This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

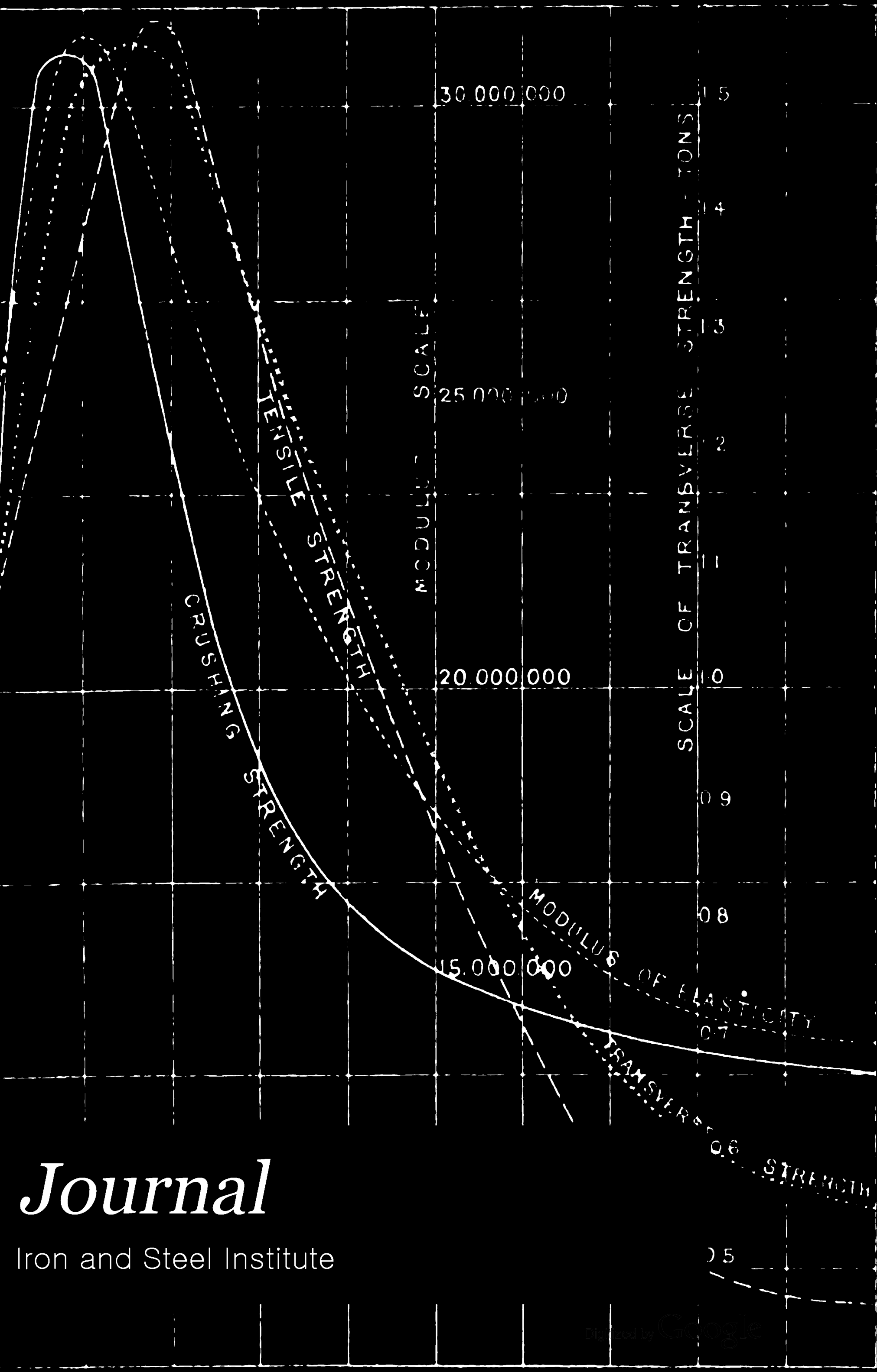
+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

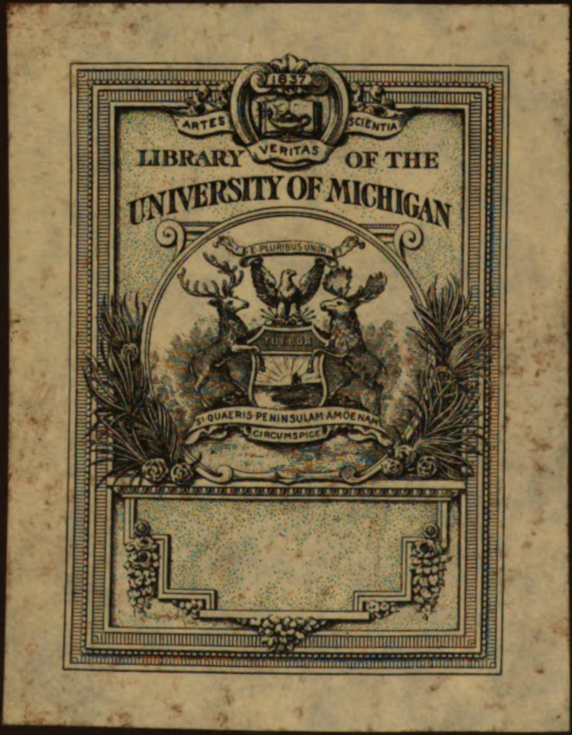
About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`



Journal

Iron and Steel Institute


1837
ARTES
SCIENTIA
VERITAS
LIBRARY OF THE
UNIVERSITY OF MICHIGAN
E PLURIBUS UNUM
TUEBOR
SI QUAERIS PENINSULAM AMOENAM
CIRCUMSPICE

East Engin.
Library

3 TP
300
.I651j

28226

No. 1.] [1886.

THE JOURNAL

OF THE

IRON AND STEEL INSTITUTE.

1886.

LONDON:
E. & F. N. SPON, 125, STRAND, W.C.
NEW YORK: 44, MURRAY STREET.

Ballantyne Press
BALLANTYNE, HANSON AND CO.
EDINBURGH AND LONDON

The Journal of the Iron and Steel Institute.

◆

I.—1886.

CONTENTS.

PAGE
NEW MEMBERS 1
REPORT OF COUNCIL FOR 1885 3
PRESIDENTIAL ADDRESS OF DR. PERCY, F.R.S. 8
PRESENTATION OF THE BESSEMER MEDAL 33
ON THE ORIGIN AND PROGRESS OF THE MANUFACTURE OF TIN PLATES, by Philip W. Flower 36
ON STEEL WIRE OF HIGH TENACITY, by the President 62
ON CERTAIN ACCESSORY PRODUCTS OF BLAST FURNACES, by T. Blair . . 81
NOTE ON A RARE BLAST FURNACE SLAG OF THE COMPOSITION OF GEHLENITE, by H. Bauerman, V.P.G.S. 88
ON BLOW-HOLES IN OPEN-HEARTH STEEL, by John Head, F.G.S. . . . 99
PRICES OF STEEL RAILS 131
ON WROUGHT-IRON CONDUIT PIPES, by Hamilton Smith, jun. 133
ON THE APPLICATION OF VERY HIGH POWERS TO THE STUDY OF THE MICROSCOPICAL STRUCTURE OF STEEL, by H. C. Sorby, LL.D., F.R.S., &c. . . . 140
ON THE ENDURANCE OF STEEL RAILS, by F. W. Webb 148
ON A NEUTRAL LINING FOR METALLURGICAL FURNACES, by M. Ferd. Gautier . 151
THE CONSTITUENTS OF CAST IRON, by Thomas Turner, Assoc. R.S.M., F.C.S. . 163
ON CERTAIN DESCRIPTIONS OF INDIAN CASTINGS, by C. Purdon Clarke, C.I.E., M.R.A.S. 200
ON EXPERIMENTS MADE WITH STEEL RAILS IN RUSSIA, by M. Beck-Guerhard . 204
DESCRIPTION OF HOT-BLAST PYROMETER—FRIED. KRUPP'S PATENT, by A. Von Bergen 207
VOTES OF THANKS 209

APPENDIX.

DISCUSSION ON MR. BLAIR'S PAPER 210
BALANCE-SHEET FOR 1885 212
OBITUARY 213

NOTES ON

THE PROGRESS OF THE HOME AND FOREIGN IRON AND STEEL INDUSTRIES.

SECTION I.—1886.

IRON ORES.

I.—OCCURRENCE AND COMPOSITION.

	PAGE
The Formation of Iron Ores	216
The Iron Ores of the English Secondary Rocks	217
Analyses of Iron Ores	217
The Vashegy-Rákos Iron Mines	218
Iron Ore in Bulgaria	219
The Age of the Hohenkirchen Iron Ores	220
The Minerals of the Province of Guipúzcoa, Spain	220
Analysis of Swedish Iron Ores	220
Norwegian Iron Ore Deposits	223
Analyses of Iron Ores	223
The Iron Ores of India	225
Iron Ore in the Hudson's Bay Territories	229
Iron Ore Deposit in Ontario	230
Iron Ore in the Central Ontario District	230
The Steel Ores of the Southern United States	230
The Cranberry Iron Ore Deposit	231
Mineral Resources of Louisiana	231
The Cornwall Iron Ore Mines, Pennsylvania	232
Iron Ore Deposits of Southern Utah	234
Geology of the Low Moor Iron Ores	235
Arkansas Manganese Ore	235

II.—MECHANICAL PREPARATION.

Ore Washer at Copake Ironworks, New York 236

III.—METALLURGICAL PREPARATION.

The Davis-Colby Calciner 237

FUEL.

I.—CALORIFIC VALUE.

PAGE
Proposed Apparatus for Determining the Heating-Power of Different Fuels 238
The Calorific Power of Fuel 239

II.—COAL.

Discovery of Coal in Scotland 239
The Coal of the Zsily Valley, Transylvania 240
The Coalfields of European Russia 240
The Pictou Coalfield 242
The Coalfields of North Carolina 242
The Jellico Coalfield, United States 243
The Classification and Composition of Pennsylvania Anthracites . 244
New Zealand Coals 246
Assays of Coal 246

III.—CHARCOAL.

A Sheet-Iron Charcoal Kiln 247
Charcoal Ovens in Tennessee 247

IV.—COKE.

The Manufacture of Coke in the United States 248
Connellsville and Virginian Coke 254
Utilisation of Coke-Oven Gases 255
The Cost of the Production of Coke at Pittsburg 255
The Relative Value of Charcoal and Coke in Blast-Furnace Practice . 256
The Blast-Furnace Value of Coke 257
The Comparative Value of Coal, Coke, and Charcoal for Blast-Furnace Purposes 257
The Relative Values of Coal and Coke for Foundry Purposes . . 261

V.—LIQUID FUEL.

The Oil Regions of Pennsylvania and New York 262
The Comparative Furnace Value of Coal and Petroleum . . . 263

VI.—NATURAL GAS.

The Geology of Natural Gas 263
Natural Gas 264
A New Gas-Well 265
Comparison of Natural Gas and Coal 266
A New Apparatus for the Perfect Combustion of Natural Gas in Furnaces 266

VII.—ARTIFICIAL GAS.

Gas Producers 267
Water Gas 269
Water Gas at Essen 272

VIII.—COAL-MINING.

PAGE
Accidents in Mines 273
Shaft Sinking by Means of Compressed Air 277
Poetsch's System of Sinking Shafts through Water-Bearing Strata . 278
Temporary Iron Lining for Shafts 278
Watertight Shaft Walling with Stone Cribs 279
New Safety Catch for Pit Cages 279
New Safety Cartridge for Coal Mines 280
On the Use of Water Cartridges 281
New Explosives 281
The Walcher Coal-Mining Machine 282
The Cost of Haulage in Anthracite Collieries 282
Transmission of Power by Steam 283
Offical Regulations for the Management of Fiery Mines in Prussia . 284
The Influence of Pressure on the Escape of Fire-Damp . . . 285
Carlton's Fire-Damp Indicator 285
Portable Electric Lamp for Mines 286
Large Output of Coal 287

IX.—COAL-WASHING.

Theory of the Apparatus Employed for Washing Mineral Substances 287
The Artois Coal-Washers at the Graissessac Mines . . . 288
Improvements in Screening Arrangements 289

REFRACTORY MATERIALS.

A Deposit of Fire-Sand in Clinton County, New York . . . 291
Fireclay in Pennsylvania 291
The Manufacture of Firebrick 291
Analysis of Bauxite 293

PRODUCTION OF PIG IRON.

I.—BLAST-FURNACE PRACTICE.

The Charcoal Blast Furnaces at Anniston, Alabama . . . 294
The Shelby Blast Furnaces, Alabama 294
A Chilled Blast Furnace Hearth 295
The North Chicago Blast Furnaces 296
The Work of the Tecumseh Charcoal Furnace 297
Plant for Iron Smelting by Water-Gas 297
The Manufacture of Spiegeleisen from Franklinite Residuum . . 299
The Distribution of the Manganese in the Spiegeleisen Furnace . 302
Ferro-Manganese Manufacture 304
The Cost of Production of Pig Iron in the United States . . . 305
The Cost of Production of Pig Iron in Alabama 307
The Formation of Ozone in Blast Furnaces 307

II.—HOT-BLAST STOVES.

PAGE
Gordon's Cowper-Whitwell Stoves 307

III.—CHEMICAL COMPOSITION OF PIG IRON.

Analyses of Austrian Pig Iron 308
Siegen Spiegeleisen 309
The Constitution of Pig Iron 309

IV.—BLAST-FURNACE SLAGS.

The Heat required for the Fusion of Blast-Furnace Slags . . 310
The Mineralogical Constitution of Slags 317
Analysis of Hungarian Blast-Furnace Slag 318
The Utilisation of Blast-Furnace Slag 318
Blast-Furnace Slag Cement 319

V.—FOUNDRY PRACTICE.

Modifications in Foundry Practice 319
The Greiner and Erpf Cupola 319

PRODUCTION OF MALLEABLE IRON.

Forsberg's Swedish Hearth 321
The Beasley Puddling Process 321
The Küpper Puddling Furnace 322
Dephosphorisation of Puddled Iron 322

FORGE AND MILL MACHINERY AND PLANT.

A 4000-ton Hydraulic Forging Press 327
Rolling Steel Wire 327
Fuel Consumption in Rolling Wire Rods 328
Leather Belt for Driving Fast-Roll Trains 328
Electric Lighting in Rolling Mills 328
Soaking-Pits for Tyres 330
Safe Working Pressure for New Boilers 330

THE PRODUCTION OF STEEL.

I.—DIRECT FROM IRON ORE.

Indian Steel 331

II.—BY THE CARBURISATION OF MALLEABLE IRON.

The Manufacture of Crucible Steel 332
Castings from Wrought Iron or Steel 335

III.—OPEN HEARTH.

PAGE
Charges for the Open-Hearth Process 336
Open-Hearth Process in Sweden 337
The Modified Siemens Furnace 338

IV.—THE BESSEMER PROCESS.

Rapid Bessemer Work 338
Modified Form of the Bessemer Converter 339
Spectroscope for the Bessemer Process 339
A Machine for Ramming Plug-Bottoms and Bricks 340
A Modified Form of the Bessemer Process 341
Bessemerising with Small Converters at Avesta 342
The Clapp-Griffiths Process 344
The Grading of Bessemer and Open-Hearth Steel at Reschitza . . 344
Grinding Basic Bessemer Slag 345
The Utilisation of Basic Slag 346

FURTHER TREATMENT OF IRON AND STEEL.

Wire Drawing without Pickling in Acids 347
Wire-Drawing 350
Steel Sleepers for Permanent Way 350
Annual Cost of Wooden and Iron Sleepers 351
The Relative Value of American and Krupp Steel Tyres . . . 351

PHYSICAL AND MECHANICAL PROPERTIES OF IRON AND STEEL.

The Electrical and Magnetic Properties of Wrought Iron, Steel, and Cast Iron in Different States of Hardness 353
The Influence of Silicon upon the Properties of Cast Iron . . 355
The Condition of Silicon in Cast Iron 359
Liquation Phenomena in Spiegeleisen 359
The Crystallisation of Wrought Iron 360
The Contraction of Iron on Sudden Cooling 360
The Porosity of Iron and Steel 362
The Properties of Iron 363
The Changes in the Texture of Steel on Heating and on Cooling . 365
The Specific Gravity of Low Carbon Steel 367
Influence of Temperature on the Strength of Iron and Steel . . 368
The Injurious Effect of a Blue Heat on Iron and Steel . . . 369
Peculiar Phenomena in the Heating of Open-Hearth and Bessemer Steel 372
The Structure of Tempered Steel 372
Tensile Tests of Iron and Steel Bars 373
The Present Value of Steel Castings 376
The Use of Ingot Iron for Boiler and Ship Plates 377
Recent Failures of Steel Boiler-Plates 378

PAGE
A Test of Boiler Steel 379
Mild Steel for Shipbuilding 380
Steel for Structural Work 381
The Weight and Section of Rails 382
Tensile Tests of Winding Ropes 383
An Autographic Test-recording Apparatus 383
New Apparatus for Measuring the Modulus of Elasticity . . 384
Bending Cast Iron 385

CHEMICAL PROPERTIES.

The Action of Certain Acids and Salts on Iron and Steel . . 386
The Action of Caustic Soda on Iron and Steel 386

CHEMICAL ANALYSIS.

I.—ANALYSIS OF IRON AND STEEL.

The Samples of Cast Iron Borings 388
The Determination of Phosphorus in Iron and Steel . . . 389
The Estimation of Phosphorus 390
The Estimation of Manganese 392
The Estimation of Sulphur in Iron 396
Silver-Foil Sulphur Test 397
The Estimation of Chromium 398
Chromium-Iron Alloys 398
Determination of Titanium in Iron and Steel 399

II.—ANALYSIS OF IRON ORES AND SLAGS.

The Estimation of Iron by Electrolysis 400
Reduction of Ferric Solutions by the Use of Amalgamated Zinc and Platinum Foil 400
Estimation of Phosphoric Acid in Basic Bessemer Slag . . . 401
Titration of Phosphoric and Arsenic Acids 401
Analysis of Manganese Ore 401

III.—ANALYSIS OF FUEL.

The Estimation of Nitrogen in Coal and Coke 402

IV.—GAS ANALYSIS.

Gas Analysis 404

STATISTICS.

I.—UNITED KINGDOM.

PAGE
Mineral Statistics 407
Iron Trade Statistics 408
Loss of Life in Mines 409
Exports and Imports 409

II.—AUSTRIA-HUNGARY.

Production and Consumption of Pig Iron 410
Ingot Iron and Steel 411
Imports and Exports 412
Iron and Coal in Hungary 412

III.—BELGIUM.

Mineral Statistics 412
Imports and Exports 413

IV.—BORNEO.

Production of Coal in Borneo 414

V.—CANADA.

Mineral Production of Nova Scotia 414

VI.—CHINA.

Coal in China 414

VII.—FRANCE.

Pig Iron, Manufactured Iron, and Steel 415
Coal 416
Imports and Exports 416
Metal Sleepers 417

VIII.—GERMANY.

Mineral Statistics 419
Production of Pig Iron 419
Imports and Exports 419

IX.—INDIA.

Coal in India 420

X.—ITALY.

Mineral Statistics 421

XI.—PORTUGAL.

PAGE
MINERAL STATISTICS 421

XII.—RUSSIA.

RUSSIAN MANGANESE MINES 421
RUSSIAN STEEL RAILS 421
THE WIRE INDUSTRY OF RUSSIA 422

XIII.—SPAIN.

THE IRON INDUSTRY OF SPAIN 422
SPANISH MINES IN 1883 423
EXPORTS AND IMPORTS 423
EXPORTS OF IRON ORE FROM BILBAO 423

XIV.—SWEDEN.

MINERAL STATISTICS 424
EXPORTS 425

XV.—UNITED STATES.

THE LAKE SUPERIOR IRON ORE MINES 425
THE COST OF PRODUCTION OF LAKE SUPERIOR IRON ORE . . . 425
IRON ORE IN OHIO 426
IRON ORE IN NEW JERSEY 427
THE PRODUCTION OF THE HIBERNIA IRON MINE, NEW JERSEY . . . 427
MANGANESE ORE IN THE UNITED STATES 427
THE OUTPUT OF COAL IN THE UNITED STATES 428
THE MANUFACTURE OF COKE IN THE UNITED STATES IN 1885 . . . 429
ALABAMA COAL, COKE, AND IRON 429
BLAST FURNACES IN THE UNITED STATES 430
THE PRODUCTION OF PIG IRON IN THE UNITED STATES IN 1885 . . 431
PRODUCTION OF IRON AND STEEL IN THE UNITED STATES IN 1885 . . 433
THE COST OF PRODUCTION OF PIG IRON IN THE UNITED STATES . . 433
THE PRODUCTION OF BESSEMER STEEL AND OF IRON AND STEEL RAILS IN THE UNITED STATES IN 1885 434
THE BESSEMER STEEL INDUSTRY OF THE UNITED STATES . . . 436
UNITED STATES IMPORTS AND EXPORTS OF COAL 437

PROCEEDINGS

OF THE

IRON AND STEEL INSTITUTE.

ANNUAL MEETING, 1886.

WEDNESDAY, MAY 12TH.

THE ANNUAL GENERAL MEETING of the INSTITUTE was opened this forenoon at the Institution of Civil Engineers, Great George Street, Westminster—Dr. PERCY, F.R.S., President, in the chair.

The Minutes of the previous General Meeting were read, approved, and signed by the President.

NEW MEMBERS.

Mr. EDWARD RILEY and Mr. A. E. TUCKER were appointed scrutineers of the voting papers, and reported, on the completion of their scrutiny, that the following candidates for membership had been duly elected, viz.:—

ALLEY, STEPHEN	Glasgow.
BEARD, GEORGE	Gartcosh.
BELL, CHARLES	Glasgow.
BELL, CHARLES ERNEST	Durham.
BROWNE, FRED. JOHN	London.
BROWNHILL, JOHN JUSTICE	Walsall.
CAWLEY, GEORGE	Manchester.
CLAUGHTON, GILBERT H.	Dudley.

Cook, Joseph	Codnor Park.
Cowper, Sinclair	Glasgow.
Craggs, Henry Foxton	Middlesbrough.
Crosland, J. F. Lovelock	Manchester.
Dalton, George	Leeds.
Dees, James Gibson	Whitehaven.
Deighton, Wm.	Workington.
Donald, Wm. J. Alex.	Glasgow.
Drown, Thomas M.	Massachusetts, U.S.A.
Dunnachie, Wm. James	Coatbridge, N.B.
Earle, Wm. Norcliffe	Cwm Avon.
Fearnclough, Walter	Sheffield.
Feldtmann, Rudolph	Glasgow.
Fleming, Robert	Glasgow.
Franks, James Peter	Sydney, N.S.W.
Frew, John	Coatbridge, N.B.
Fyfe, John	Glasgow.
Gilmour, Allan, Jun.	Maryport.
Gledhill, John M.	Manchester.
Görasson, A. H.	Sandviken, Sweden.
Grant, T. Maxwell	Glasgow.
Griffiths, Azariah	Falkirk.
Hay, Alex. Marshall	Glasgow.
Hill, Joseph	Barrow-in-Furness.
Hirst, Daniel	Dowlais.
Hodson, James	Stoke-on-Trent.
Horsburgh, Robert	Glasgow.
Jones, Daniel	Dowlais.
Kalakoutsky, Gen. Nicholas	St. Petersburg, Russia.
Kendall, J. Dixon	Whitehaven.
Kerr, Andrew	Ardeer, N.B.
MacKinnon, William	Glasgow.
MacLellan, Wm. Turner	Glasgow.
Mathieson, Thomas A.	Glasgow.
M'Donald, William	London.
M'Millan, John, Jun.	Dumbarton.
Miller, J. Ritchie	Glasgow.
Miller, Thomas	Edinburgh.
Milling, Thomas	Wigan.
Mudd, Thomas	Hartlepool.
Paterson, Anthony	Dowlais.
Paterson, T. S.	Motherwell, N.B.
Polson, John	Greenock, N.B.
Resimont, Armand	Valenciennes, France.
Russell, George	Coatbridge, N.B.
Samuel, James	Glengarnock, N.B.
Shanks, Thos., Jun.	Johnstone, N.B.
Share, Geo. W.	London.
Simpson, Robert	Harrington.
Sorby, Henry C., F.R.S.	Sheffield.
Steel, Henry, Jun.	Sheffield.
Steel, Wm.	Sheffield.
Storr, Walter W.	Landore.
Thompson, Robert	Sunderland.
Turner, Thomas	Birmingham.

Varley, John	Leeds.
Verley, Ernest	Glasgow.
Walker, C. C.	Donnington.
Whitelaw, Thomas	Glasgow.
Whiteley, Henry J.	Ulverston.
Wilson, Matthew G.	Glasgow.
Wilson, R. Theo.	Middlesbrough.
Young, Robert	London.

REPORT OF COUNCIL.

The General Secretary, on behalf of the Council, submitted the following as their Report for 1885 :—

The Council of the Iron and Steel Institute, in submitting to the Members their Sixteenth Annual Report, have pleasure in being able to point to the continued prosperity of the Institute, alike in respect of membership and finances.

The total number of names on the List of Members at the end of 1885 was 1311, as compared with 1290 at the end of the previous year.

Seventy-one names are proposed for election at the present Meeting, which, if all are elected, will increase the membership of the Institute to 1382.

The Members who have been removed by death during the twelve months ending December 31, 1885, were—

George Frederick Adams.
George Bedson.
Peter D. Bennett.
The Earl of Dudley.
James Eadie.
H. M. Mackenzie.
Jean Batiste Menart.
Hugh Neilson.
Walter Neilson, Glasgow.
Thomas J. Perry.
Sidney Gilchrist Thomas.
Thomas Udall.
William Watson.
George Wilson.

As usual, two General Meetings of the Institute were held during the year 1885, at which the following Papers were read and discussed :—

At the Spring Meeting in London.

On the Blast Furnace Value of Coke from which the Products of Distillation from the Coal used in its Manufacture have been collected. By Sir Lowthian Bell, F.R.S., Middlesbrough.

On more Recent Results obtained with the Simon-Carvès Coke Ovens, especially as regards Coal Tar. By Mr. **WATSON SMITH**, the Owens College, Manchester.

Note with Reference to the Methods Proposed for Coking Coal and Recovering Volatile Matters. By Mr. H. E. **ARMSTRONG**, F.R.S., London.

On the Simon-Carvès Coking Process. By Mr. **HENRY SIMON**, Manchester.

On the Properties of Malleable Iron Deduced from its Microscopic Structure. By Dr. **HERMANN WEDDING**, Berlin.

On Natural Gas, and its Utilisation for Manufacturing Purposes in the United States. By Mr. A. **CARNEGIE**, New York, U.S.A.

On a Modified Type of the Siemens Gas-Producer, whereby the Gases are enriched and the By-products Recovered. By Mr. J. **HEAD**, London.

At the Autumn Meeting in Glasgow.

On the Iron Trade of Scotland. By Mr. F. J. **ROWAN**, Glasgow.

On the Rise and Progress of the Scotch Steel Trade. By Mr. **JAMES RILEY**, Glasgow, *Member of Council.*

On the Present Position and Prospects of Processes for the Recovery of Tar and Ammonia from Blast Furnaces. By Mr. **WILLIAM JONES**, Langloan Ironworks, N.B.

On the Value of Silicon Pig to the Ironfounder. By Mr. **CHARLES WOOD**, Middlesbrough.

On a New Form of Cupola Furnace. By Mr. **JAMES RILEY**, Glasgow.

Notes on Steel Shipbuilding. By Mr. J. H. **BILES**, Clydebank, Glasgow.

On the Forth Bridge. By Mr. **BENJAMIN BAKER**, M.I.C.E., London.

Four other papers were offered for the Glasgow Meeting, but were unavoidably held over until the Spring Meeting in London, viz. :—

On the Tin-Plate Manufacture. By Mr. **PHILIP W. FLOWER**, Neath.

On a New Form of Pyrometer. By Mr. A. **VON BERGEN**, Darlington.

On the South Chicago Blast Furnaces. By Mr. F. W. **GORDON**, Philadelphia, and Mr. E. C. **POTTER**, Chicago.

On Certain Accessory Products of the Blast Furnaces. By Mr. **THOMAS BLAIR**, Wingerworth, Chesterfield.

The Autumn Meeting of the Institute was held in Glasgow, in response to a very cordial invitation received from the leading iron and steel manufacturing firms in that city and its neighbourhood. The Meetings and Excursions together occupied five days. A very large and influential Committee was formed in the West of Scotland for the reception and entertainment of the Institute, of which the Lord Provost of Glasgow was Chairman. The arrangements were carried out by an Executive Committee, presided over by Mr. James Riley, and were remarkable for the complete and thoughtful manner in which they met every requirement of the occasion. Great liberality was shown by the owners of works in the district in admitting Members to witness their operations, and the North British, Caledonian, and Glasgow and South-Western Railway Companies merit special recognition for the hearty co-operation which they ungrudgingly rendered in making the Meetings and Excursions successful, and more particularly for the special free trains which they placed at the disposal of Members. The Council have warmly thanked all those who contributed towards making the Meeting of 1885 one of the most enjoyable which the Institute has ever held.

At the last Spring Meeting of the Institute, Dr. Sorby, F.R.S., delivered an interesting lecture, illustrated by examples, on the Microscopic Structure of Iron and Steel. Learning from the author that he proposed to pursue his investigations, and that he would be glad to present the results to the Institute, the Council, at Dr. Sorby's request, deferred the publication of his interesting lecture. Dr. Sorby has since then continued his inquiry, and the first fruits of it are recorded in the Paper which he has prepared for the present Meeting.

It affords the Council much satisfaction to mention that their esteemed colleague, Sir Henry Bessemer, has presented to the Institute the interesting case of early specimens of the steel that bears his name, which he exhibited at the International Inventions Exhibition, and in respect of which he received a gold medal on that occasion.

A list of the donations to the Library of the Institute during the year 1885 was published in the last issue of the *Journal* (No. II., 1885), and the Council desire to thank the donors of the same, especially the British Admiralty, who have presented a copy of the Report of the Committee appointed to inquire into the causes of the deterioration of boilers, with valuable appendices, showing photographs of fractures, &c., and the United States Government, which has presented the Memoirs of the Geological Survey of that country and the Reports of the Tenth Census.

The Bessemer medal for 1886 has been awarded to Mr. Edward Williams.

The Vice-Presidents and Members of Council who, in accordance with the rules, retire at the present Meeting, are—

Vice-Presidents.

Sir John Alleyne, Bart.
Mr. R. Heath.
Mr. E. Fisher Smith.

Members of Council.

Mr. Bleckly.
Mr. Hewlett.
Mr. Gilchrist.
Mr. Horton.
Mr. Snelus.

all of whom are eligible for re-election. As no other nominations have been received, the Council propose the re-election of their retiring colleagues.

The HON. TREASURER (Mr. Dale) submitted the Financial Statement, which appears in the Appendix. It would be seen, he stated, that the income for 1885 was £2780, 0s. 5d., and that the expenditure was £2248, 12s. 7d., so that the income exceeded the expenditure by £531, 7s. 10d. On the other hand, contrasting the income and expenditure for 1885 with that of 1884, it would be found that there had been a decrease in the income of the past year of £118, 2s. 5d., and a decrease in the expenditure of £42, 17s. 4d. The decrease in the income for 1885 as compared with that of 1884 arose entirely from the fact that members' subscriptions were more in arrear during the last year than they were in the previous year. The Report of the Council had stated that the total number of members was 1311, while the treasurer had received for 1885 subscriptions from only 1078 members, but in 1884 he had received, by the same date, subscriptions from 1129 members. He referred to the subject because it might be desirable to impress upon members the desirability of paying their subscriptions promptly, thereby not only enabling the accounts to exhibit more accurately the condition of affairs, but also saving considerably the time both of the Secretary and himself.

The PRESIDENT said he had great pleasure in moving the adoption of the Report and Financial Statement, which he trusted the members would regard as satisfactory.

Sir LOWTHIAN BELL, Bart., F.R.S., seconded the motion, which was unanimously adopted.

Mr. JEREMIAH HEAD begged to move a vote of thanks to the Council for the way in which they had conducted the affairs of the Institute during the past year. Since everything had gone on smoothly and pleasantly, it might be imagined by some that those who did the work had had no trouble whatever. But any one who had been closely connected with the practical working of an Institution of that kind would know well that it always involved a great deal of time, a great deal of energy, and not a little expense. He was quite sure that in the present case the necessary efforts and sacrifices had been cheerfully made, and that the members would not be slow in recognising and appreciating them.

Mr. JOHN CORNER seconded the motion, which was agreed to.

Mr. B. WALKER said he rose to propose a vote of thanks to their distinguished treasurer, Mr. Dale, for his very valuable services in connection with the Institute. It was not necessary to dwell upon Mr. Dale's many excellent qualities; they all knew that he was a man of great exactness, who might be relied upon in every way. He hoped that the members would take the hint which Mr. Dale had given and pay their subscriptions more promptly. He hoped that hard times had not been the cause of their not paying with greater punctuality during the past year. But whatever the members might have done—however they might have performed their duties—Mr. Dale had certainly performed his efficiently.

The vote of thanks was duly seconded, accorded by acclamation, and acknowledged.

The **President** then delivered the following address:—

PRESIDENT'S ADDRESS.

Gentlemen,—It is not, I am informed, expected that a President of the Iron and Steel Institute should, during his two years' term of office, make more than one communication to the members, dignified with the appellation of Address; and although this precedent has not been invariably followed, yet it is not my intention on the present occasion to depart from it. I propose, however, as succinctly as I can, to preface the proceedings of this annual meeting by some remarks, which, I trust, you will consider to be not inappropriate; and I shall be particularly careful to avoid touching on any question of a controversial character.

I am happy to inform you that the number of papers to be read and discussed is amply sufficient—if, indeed, not more than sufficient—to engage your attention during the whole term of this meeting. The subjects of these papers extend over a wide range, some being eminently scientific, and others eminently practical, thus fulfilling what I conceive to be the great objects of the Institute, and the intention of its founders, namely, the promotion and advancement of the science and art of the manufacture of iron and steel. Some of the papers are short, and some long; but it will not surprise me to find that the discussion of certain of the former will occupy much more time than that of the latter, not on account of their greater inherent excellence, but because they deal with questions of vast economic importance and of general public interest. I allude especially to the paper on the Endurance of Steel Rails, by my friend, Mr. Webb, of Crewe, and that on Wrought Iron Conduit Pipes, by my friend, Mr. Hamilton Smith, junior, of the United States of America, both of whom have, at my request, been induced to make these communications. Mr. Smith has had large and long experience in hydraulic engineering in California.

Dr. Sorby, F.R.S., continues to be actively engaged in prosecuting his elaborate researches concerning the microscopic structure of iron and steel, which he commenced twenty years ago; and the complete results of which, I am happy to state, will be published, at as early a date as possible, in the *Transactions of the Institute*, accompanied with beautiful illustrations by what is known as the Woodbury type process. It is to Sir Henry Bessemer that we owe the selection of this mode of illustration, which he did not recommend until he had satisfied himself and others of its suitability. Dr. Sorby informed me not long ago that he had succeeded in contriving an optical arrangement, by which he could avail himself of much higher magnifying power than previously in studying the microscopic structure of steel, a contrivance which is described in his paper to be read to this meeting. The microscopic structure of iron and steel, particularly of steel of varying degrees of hardness induced by tempering, has of late excited, and is still exciting, much attention both at home and abroad. Speaking for myself, I have a strong impression that, from a scientific point of view, great results are likely to flow from this line of investigation, which may possibly admit of valuable application in the manufacture and working of iron and steel. I have long been convinced that it is only by physico-chemical investigation that our present ignorance of the causes of many phenomena relating to iron and steel will ever be lessened or dispelled. I have sometimes fancied, or, perhaps, dreamed, that what we call iron might not, after all, prove to be a single element, in the chemical sense of that term; and I am not, I think, the only person who has shown such signs of what most of my audience will probably regard as mental aberration. To my friend, Dr. Sorby, I look forward as the physico-chemical physician who will cure me of such insanity; and I venture to assert, from an intimate knowledge of him and his works, that there is no man, either in Great Britain, Europe, or America, who is more worthy of confidence as an accurate observer. In these days the dominion of what is called science is so vast in extent, that no explorer can travel over more than a very small, I might even say infinitesimal, part of it. Life is so short, and man's capacity so bounded, that it is only by restriction, by specialisation, that he can hope to advance human knowledge. Dr. Sorby has shown how much may be done by concentrating mental energy on a special field of research, and, I feel sure, you will all join with me in hoping that he may be spared for many years, and gather fresh laurels by his achievements in dispelling much of the mystery in which the subject of steel is still involved.

While it is not my intention to pass in review all the various papers to be read at the present meeting, yet I think it may be convenient to you that I should mention some of them. There is a paper on the Composition of Cast Iron, by Mr. Thomas Turner, which is an answer to the general invitation in my Address of last year to chemists, having the opportunity of investigating interesting questions affecting iron and steel, to communicate their results to the Institute. I refer to it solely to show how the circulation of questions by means of our published *Transactions* may, like the scattering of seed, bring forth good fruit. Mr. Turner is a young man connected with the Mason College of Science in Birmingham, who has evinced a strong predilection for iron and steel as subjects for experimental investigation. He has previously published some excellent papers on these subjects. Having, since the meeting of the Institute at Glasgow last autumn, had the pleasure of making his personal acquaintance, I have done my best to encourage him to follow this line of inquiry which promises so rich a harvest.

When I had the honour of first addressing the Institute, I ventured to suggest that it might be desirable to propose for solution specific problems relating to iron and steel, as there are many young men scattered throughout the kingdom who are well qualified to deal with such problems; and I know, from my own experience, that it is not always easy for a young man to make a judicious selection of subjects for research. After much reflection, I venture to say, that in my humble opinion the course suggested is, at least, worthy of the serious consideration of the Institute. It must be understood that I alone am responsible for that suggestion. Moreover, I think it might also be desirable to confer a medal or other reward on the author of a paper who may have conclusively solved a problem emanating from the Institute, especially if its solution has required long-continued labour and been attended with considerable expense.

Now there are many young men who might be very willing to attempt the solution of a problem, but would be deterred from doing so on account of the cost. To such, in the event of a successful issue, a pecuniary reward might be given sufficient at least to cover the expenditure. But to this a severe moralist might perhaps object, on the ground that it would be an inducement to a young man to incur a risk and contract an obligation, which, in the event of failure, he might find it difficult to discharge. There is no doubt some reason for this objection; yet, if I mistake not, the young men of the present day are pretty well able to take care of themselves. It will be observed that, should the Institute ever be disposed to adopt this course, *it* would certainly incur no risk; for the pecuniary reward would be conferred only for work actually done, and decided by competent judges to be worthy of it. This differs widely from what was so strongly and perseveringly urged some years ago under the alluring term of Endowment of Research, by which it was proposed to capture budding philosophers, and bind them by a golden chain to the service of science for life. But what assurance could be given, it was properly demanded, that after a man has once been permanently and even munificently endowed, he would spend the rest of his days in what is called, to use a clap-trap phrase, the interrogation of Nature? Are there not instances of men who have done excellent work in the way of original research before endowment and none afterwards? That there are men of great intellectual power who, if freed from the ordinary cares of life, would labour without intermission in the cause of science to the end of their days and add greatly to the sum of human knowledge, cannot be doubted. But who is to discover them? That is the difficulty. Men of science, so called in popular language, are for the most part just like other men, and partake of all the failings of humanity. They are often believed to be lowly, meek, and retiring, regardless of sublunary affairs, and wholly engaged in the worship of Nature. But I need not remind you that there are certainly some exceptions.

In my first Address I alluded to the possible formation by the Institute at some future time of a collection illustrative of special points of interest, relating to the manufacture and uses of iron and steel. I had not the faintest notion that what I then suggested as a possibility would, within the short space of a year afterwards, be realised. With the unanimous approval of the Council, the first step in that direction has been taken by their acceptance of the generous and valuable gift of Sir Henry Bessemer. That gift consists of a series of specimens illustrative of the early history of the process universally known by his name, and which series he exhibited at South Kensington some months ago. Each specimen has a special interest of its own, and all are equally deserving of the most careful inspection. The history of the metallurgic arts is involved in the history of the civilisation of man, and is, therefore, to every cultivated mind, a subject worthy of study. But there is no branch of those arts which has produced so vast an influence on the destinies of the human race as that relating to iron and steel. However sad may be the reflection that those metals have, in the hands of the warrior, been mighty instruments for inflicting immeasurable suffering and ghastly death; yet, on the other hand, in the hands of the man of peace, they have also been mighty instruments of civilisation. They have lessened the toil of men in their struggle with the reluctant earth to make her yield her fruit, increased their domestic comforts, and enabled them to travel with safety, speed, and certainty even to far distant realms. Steel, as you know, has of late been largely concerned in promoting our material progress, especially in locomotion, and is now all but universally used as the metal for rails, on account of its much greater durability than wrought iron, and its comparatively low cost of production. For the same reasons its application to other useful purposes has been widely extended. These results, so advantageous to all the nations of the earth, have mainly flowed from the ingenuity of one man, and that man, it should be remembered, not educated in the orthodox creed of an ironmaster. He invented an entirely novel and simple process, by which steel could be rapidly and economically made on a large scale from pig iron, and thereby effected a revolution in an art which has justly rendered his name illustrious. But at first he had to encounter many trials and difficulties, which by the vigorous exercise of his fertile inventive faculty, and by his indomitable perseverance, he eventually overcame. The originality which he displayed in the construction of suitable machinery for his process has always greatly impressed my mind, and seemed to me not inferior to that shown in the first conception of the process. Now, gentlemen, I feel sure you will cordially join me in thanking Sir Henry Bessemer for presenting to the Institute his most valuable and instructive collection of specimens, the material representatives of his earliest labours, and the first instalment of what, it is to be hoped, will one day become a museum worthy of the Institute. It may be reasonably imagined that, should the British Constitution survive, these specimens will be looked at with singular interest, and regarded, I might almost say, with veneration by many a generation to come. In my humble judgment they are more to be desired by members of the Iron and Steel Institute than ingots of fine gold of equal weight; and, if guarded with reverential care from the fingers of man and the action of the atmosphere, I am disposed to think they will prove to be more enduring than if they consisted of gold, inasmuch as, in the possible event of an invasion of the chambers of the Institute by an uproarious and triumphant mob, intent only on mischief and plunder, they would not, like objects of gold, excite the cupidity of such eminently patriotic and respectable citizens. A recent event has fully revealed the diabolical propensities of the genuine metropolitan "rough," and shown that such mischievous vagabonds are only to be kept in order by the exercise of physical force. Who, then, will venture to deny the possibility of the occurrence of such an untoward incident as that which I have imagined? Who knows whither we are travelling? Who, without some misgiving, can look forward to the future, which, though dim, may not be distant? We are not yet in a state of stable political equilibrium, or of happy millennial rest. But let us cherish the hope, that, whatever may happen, the British empire may last unmutilated for ages to come, and continue, as in ages past, to hold its high position amongst the nations of the earth. Let us console ourselves with the reflection, that however potent an instrument muscle may be in maintaining liberty and good order in the commonwealth, it is powerless without a directing brain. It is the combination of intellectual and physical force that really rules the world. It may be the fashion now-a-days in some quarters to speak disparagingly of the wisdom of the educated; but, if I mistake not, you will agree with me in thinking, that, in dealing with complex social and political problems, it is infinitely to be preferred to that of the easily excitable, less informed masses. This reminds me of the saying of a dear friend of mine, now deceased, namely, that "the aggregate of ignorance can never constitute knowledge."

There is a well-known legal phrase, *de minimis not curat lex,* in which is pithily expressed the rule, by which the lawyer is guided in forming his judgment on the merits of a case. Thus, in his estimation, there are things or circumstances too small and insignificant to be deemed worthy of consideration; and, accordingly, he ignores them. But this rule does not apply to the man whose subject is the investigation of iron and steel; for there is *no* thing or circumstance, however little, relating to them that does not deserve his careful attention. The purely practical ironmaster may, possibly, be inclined to dissent from this proposition, holding that all knowledge of those metals is valueless which cannot be made immediately subservient to his personal advantage. As I do not suppose any member of the Institute would endorse such an opinion, it would be wasting time to controvert it; but were it necessary to do so, I feel sure that I could point to many an apparently sterile and useless fact, which, after having lain dormant for years, has eventually proved to be highly productive in a commercial point of view. And in any case, it is certain that no man can predict with confidence that a fact, which at first seems to be one of mere scientific interest, will not ultimately be found valuable in practice. I touched on this subject in my Address of last May; and my reason for now doing so again is to invite your special attention to certain communications to be submitted to you on matters which, at the first glance, might seem too insignificant and unimportant to merit serious consideration.

You may all have heard of the occurrence in the hearths of iron-smelting blast-furnaces, of what has been erroneously designated "furnace amianthus;" but probably few of you have had the opportunity of seeing it, and fewer still of observing it *in situ.* This substance is, in my judgment, one of extraordinary scientific interest. In 1864 I published a description of it, and, if I err not, all that was known about it at that time. But it was not till several years afterwards that I first saw a specimen of it, which was brought to me by a mineral collector who found it in slag from a blast-furnace in Scotland. It is white, and of a finely fibrous structure, and here and there it is distinctly seen to consist of more or less globular aggregations of radiating fibres. It is associated with minute brilliant crystals of cyano-nitride of titanium; and, freed from these, it was found by analysis to contain 97·5 per cent. of silica, the remainder consisting of oxide of iron and manganese, with traces of lime and magnesia. Last year Mr. Blair, blast-furnace manager of the Wingerworth Iron Works, near Chesterfield, presented me with much larger specimens, and one of immensely larger dimensions than any I had previously seen, and which I venture to characterise as superb, and the sight of which affords me delight. Having long known Mr. Blair to be an expert analyst, I immediately tried to induce him to analyse the material of these specimens, and to communicate the result to the Institute, and at the same time to impart the fullest information in his power as to the furnace conditions accompanying their formation, the precise locality in the furnace where he discovered them, and any other particulars which might tend to throw light on their mode of formation. Mr. Blair, I am glad to say, adopted my suggestion, and prepared a paper on the subject for the last meeting of the Institute at Glasgow; but owing to the copious supply of valuable papers, especially from our Scotch members, relating to the processes conducted at iron and steel works in the vicinity, which all the members of the Institute had been most courteously invited to visit, and which necessarily were highly attractive to those not residing in Scotland, the reading of several papers, including that of Mr. Blair, had to be postponed until the present meeting. Now the occurrence of silica in the manner described is, I venture to assert, a fact of high scientific interest; and it certainly presents a problem which perplexes me, and of which I am quite unable at present to propose a solution.* I have to express my hope that the reading of Mr. Blair's paper will excite discussion, and that, at least, some light will be thrown on the subject, particularly on the source of the silica, and the cause of its existence under the circumstances stated. I cannot conclude these few remarks without expressing my gratitude to Mr. Blair for his gift to me of this noble specimen of blast-furnace fibrous silica which you see before you. In my eyes it is more valuable than a mass of gold of equal weight. I often look at it, and every time with increasing pleasure.

---

* See Note 1, p. 25.

There is another paper to which I beg to direct your attention, and, although it is presented in my name, yet, for reasons I will presently state, I think I may do so without exposing myself to the imputation of egotism. It is that of which the subject is a rare blast-furnace slag. After my return to London from Glasgow, I was favoured by Mr. Aitken of Falkirk with some specimens of a crystallised blast-furnace slag from Scotland which excited my interest, because it seemed to differ in some respects from any in my own extensive collection of such products. I accordingly requested my friend, Mr. Edgar Jackson, to analyse this slag, a request with which he immediately and most willingly complied. The result showed that its composition is very nearly identical with that of a blast-furnace slag from the Oldbury furnaces, South Staffordshire, which I had analysed in 1846, and found to have practically the same composition as the natural mineral named Gehlenite, and of which an account was published in a joint-report to the British Association from the late Professor Miller, the distinguished professor of mineralogy at the University of Cambridge, and myself. If I mistake not, that was the first announcement of the artificial formation of this mineral either in an iron-smelting blast furnace or otherwise. I have not since met with a slag of the same composition, except that for which I am indebted to Mr. Aitken. But I have something to add concerning this slag, which I am sure will interest my audience. Knowing that my friend, Mr. Bauerman, had specially studied the physical characters of minerals, I requested him to examine this slag with respect to those characters, and, as I expected, he with hearty goodwill readily consented to do so; and the result is that, aided by the microscope, he has discovered diffused through the crystals of this slag minute yet well-formed octahedral crystals of a spinel (the typical chemical formula of which is $3RO, Al^2O^3$,—R representing bases of the lime series). Ample details, both chemical and physical, concerning the slag will be found in the printed paper drawn up by Mr. Bauerman. It will be perceived from what I have said that, with regard to this paper, I have only acted as the vehicle for its communication to the Institute. It is to be considered, as, in fact, it is, the joint contribution of Mr. Bauerman and Mr. Jackson. Both of these gentlemen, I have extreme satisfaction in stating, were my students in the early days of the School of Mines in Jermyn Street; and no reward can be so great to a teacher as that of having been the humble means of assisting his students in achieving distinction. Whatever aid I may have rendered them in their youth, I acknowledge, with gratitude, how amply I have been repaid by their invariable kindness in assisting me in the study of metallurgy, and for the valuable information on that subject which they have never failed from time to time to impart to me when they thought it would be acceptable. And, indeed, I am under the same obligation to many other old students of mine, who have done good and honourable work, not only in this country, but throughout the world. Although my labours as a teacher came to an untimely end some years ago, yet I have always pleasure in looking back on my connection with the old School of Mines, of which the teachers had to struggle hard for many a weary year before they succeeded in bringing it to maturity.

It is not without some misgiving that I venture further to try your patience by discoursing of things which may seem insignificant. The first of these things is a vessel or pan made of thin cast-iron, which is commonly used by the Chinese for culinary purposes, such as boiling rice, and a specimen of which has been placed on the table before you. No description, therefore, from me is necessary to enable you to form an accurate conception of its shape and size. You will, I think, be struck with the thinness of the metal, a point to which the Chinese attach much importance, because it favours economy in the consumption of fuel. A description of such pans was published by Count Rumford in 1802.* My friend Dr. Lockhart, brother-in-law of the late Sir Harry Parkes, and for a long period engaged as a medical missionary in China, informed me that many years ago a large quantity of pans, of the same shape as that before you, was made in Birmingham and exported to China; but the natives would not buy them, as they were too thick and wasted firewood. The pan here exhibited has been presented to the Institute, and has, unfortunately, been accidentally cracked. But such is often the fate of the Chinese pans, owing to their thinness; and such is the skill of the Chinese tinker, that a cracked and even broken pan may be easily and quickly repaired, and made as good as new.* We are indebted to our member, Mr. Gilchrist, for an analysis of the metal of this pan, which another of our members, Mr. Edward Riley, made at his request. It consists *per cent.* of

---

* "Essays, Political, Economical, and Philosophical." By Benjamin Count Rumford. 1802, vol. iii. p. 298.

Carbon (combined)	3·638
Carbon (graphitic)	0·788
Silicon	0·049
Sulphur	0·019
Phosphorus	0·081
Manganese	*nil.*
Copper	*nil.*
Iron	95·422
	99·997

The questions of particular interest, which, I think, careful inspection of this pan will excite, are of what kind of material was the mould made? how was the mould fashioned? and was it strongly heated when the metal was poured into it? Perhaps it may not be too much to hope that members of the Institute, or others specially skilled in the art of founding, may hereafter express their opinions on those questions, or on any others bearing on the subject which may occur to them.

There now remains only one other little thing to which I crave your attention. It is the small article which I hold in my hand, and with which a Hindoo woman encircles her legs, in the hope, I presume, of enhancing her charms. It is an anklet consisting of links of brass,† each of which is gracefully curved and prettily ornamented with a floral pattern, and in design, as a whole, it would do no discredit to a school of art of the western world. Its cost is trifling and amounts only to a few pence. But its interest is founded on the fact, that it is a single casting, and yet each link is separate. It is this article which will form the subject of a paper by my friend, Mr. Casper Purdon Clarke, who holds a responsible position at the India Museum, and which paper he has obligingly communicated at my request. He procured the specimen when in India. When he showed it to me not long ago, and assured me that it was cast in one piece in a mould, I was fairly puzzled in trying to conceive how this could be done, and other persons, who have seen it, have also been equally puzzled with myself. My practical knowledge of the art of moulding and casting being exceedingly limited, what has perplexed me may be clear enough to an expert in that art; but as my audience may not wholly consist of such experts, I hope I shall not be accused of having wasted your time by bringing this subject before you.

---

* I gave a full account of the mode of reparation in my volume on Iron and Steel, published 1864, pp. 747 *et seq.*

† My friend, Mr. Edgar Jackson, has obliged me by making a quantitative analysis of it. He has found it to consist mainly of copper and zinc, with a little lead and some iron. It contains neither tin nor silver.

The study of metallurgical processes practised amongst Eastern nations has always had a peculiar charm for me, and especially such as relate to iron and steel. It is, I think, not improbable that cast iron was first intentionally produced and applied in China. Although it is true that it may be formed in the primitive method of directly extracting iron in the malleable state from the ore in Lilliputian furnaces not larger than a chimney-pot, yet it is only in very small quantity, and occurs in small globules intermixed with the charcoal left unconsumed at the end of the process, and which globules are actually collected by the native iron-smelters in India, and used for the same purpose as leaden shot by our sportsmen. But, in this case, the production of cast iron is merely accidental, and, so far as I am aware, it was never applied except in the manner stated. In India the casting of steel originated; and in former times Indian steel, known by the name of "wootz," had a world-wide reputation. Then let me remind you of those marvellous sword-blades, sharp as a razor, and so tough that, unlike some modern weapons of steel, they might be wielded by the strongest arm against an enemy without risk either of bending or breaking. For a graphic and, at the same time, picturesque description of such sword-blades, let me refer you to Sir Walter Scott's exciting novel of "The Talisman." The metal of which they consisted was an elaborately interwoven mass of iron and steel, the surface of which, by the action upon it of certain corrosive liquors, yielded that exquisitely beautiful pattern or damask, the name applied to figured silks, linen, &c., imported from Damascus.* One of the most remarkable illustrations of this intermixture of iron and steel which I have seen is that presented by dagger-blades, the surfaces of which bear the design of what is termed "Mahomet's Ladder." This is produced by so working and welding the metal as to make it show the appearance of transverse bars at regular intervals from top to bottom of the blade; and to do this with such remarkable precision must have required extraordinary skill in manipulation. The time occupied in making damascened sword-blades of first-rate quality was, doubtless, very considerable, if we may judge from the nature of the material and of the high price paid for the swords. But there is another circumstance which, if its truth should be established, would interest my audience. I allude to the mode of tempering. My friend Mr Woolner, R.A., informs me that he had somewhere read an account of the process, in which it was alleged to be that of gently hammering or rather tapping the blade in a cold state from end to end during a long time. It is said that in tempering the sword-blade of the renowned Saladin, a man was employed every day for a whole year!

I feel sorely tempted to say something on the subject of Japanese metal-work, which, in respect of design, variety, skill, and to us novelty also, in manufacture, is equally interesting and attractive. But I forbear to trespass further on your patience. There is, however, one subject relating to the East which I cannot pass over in silence. It is the prospect of China becoming at no distant date a large producer of iron and steel. She has enormous coal-fields containing every variety of that fuel, and in quality it is undoubtedly equal to the best occurring elsewhere, either in Europe or America. I have assigned my reasons for that statement in a volume on fuel, which I published in 1875, and the additional knowledge which I have since acquired has only tended to confirm the truth of that statement. China has also, I believe, an abundant supply of excellent iron ores, of which I examined some a few years ago from the province of Chih-li; and I may be permitted to state, that in the volume just mentioned is an important communication on this subject, from a competent and trustworthy observer long resident in China, I mean Mr. Henderson. The superstitious belief amongst the people, called "*Fung Shui*," has, it is affirmed, been an insurmountable obstacle to the opening and working of Chinese mines in a satisfactory manner; but, on the other hand, I have heard it contended that this superstition was encouraged by the authorities in China for reasons best known to themselves, of which one possibly may have been the desire of retarding the material progress of the people, and so checking the development of a spirit of freedom regarded as likely to interfere with the interests of those authorities.*

---

* Wedgwood's *Dictionary of English Etymology*, 1872, p. 197.

I have now to propose what to me is a most agreeable duty, namely, to express as adequately as I can my gratitude, and I am sure I may add yours also, to our Scotch members and friends, for the warm and hearty welcome which we received from them when we visited Glasgow last autumn. We are also greatly indebted to the Lord Provost and other municipal authorities of that venerable city for their kindness and unremitting attention. Nothing was left undone to promote our comfort and render our visit agreeable, and, at the same time, profitable in the way of instruction. The directors of the various railways communicating with the surrounding country, deserve our cordial thanks for their liberality, and for the special arrangements which they made for facilitating our excursions to the neighbouring iron and steel and other works. But to one of our members, resident in Scotland, we are pre-eminently indebted. He spared neither time nor labour in striving to make the meeting memorable in the annals of the Institute; and that he succeeded in doing so I need hardly remind you. The gentleman to whom I refer is Mr. James Riley, of the Steel Company of Scotland; and if it were permissible on the present occasion, I would gladly propose thanks to Mr. Riley for the skill, energy, and devotion which he displayed in his endeavours to promote the objects of the Institute at its meeting in Glasgow in 1885. And I should like also to propose a vote of thanks to the proprietors and managers of the various works which we were so generously invited to visit, for the kind attention and for the warm hospitality we received. How warm and genuine that hospitality was I need not tell you. The blood of the grape flowed freely, and so did the spirit of barley.

---

* See Note 2, p. 25.

Notwithstanding the prevalent notion that the inhabitants of the genial South are less able to contend with the products of fermentation than those of the more rigorous North, yet the former showed no disinclination to test the truth of that notion by experiments upon themselves.

But in one respect, and in one respect only, our visit to Glasgow was attended with regret, and that was inevitable, as it was due to the fact that it is impossible for a man to be in two or more places at the same time. The excursions were so numerous, that some of them necessarily occurred simultaneously on the same day to localities widely apart. Each member of the Institute had, therefore, to exercise a choice with respect to excursions, and select such as might, for one reason or other, appear to him most attractive. For my own part, I can truly say that, had it been possible, I should gladly have joined every one of them; for there was not one from which I should not have derived both pleasure and instruction. I had set my heart on a visit to the Carron Ironworks, so memorable in the annals of the iron manufacture of Scotland; and was greatly disappointed that I was obliged to forego that pleasure, especially when my friend Mr. Cowper, after his visit to those works, told me how much he had seen there to interest him, and how admirable were all the arrangements for moulding and casting. The Calder Ironworks I had also looked forward to the pleasure of visiting, on account of their historic association with the first introduction of the hot-blast, but was, unhappily, denied it.

There remains only one other incident connected with our visit to the North, which I cannot refrain from noticing, and that is the excursion to Inveraray Castle. Although the weather in the early part of the day was not quite so propitious as might have been desired, yet it afterwards cleared up as we steamed along the Clyde from Greenock in the magnificent steel-ship *Columba*, one of the swiftest vessels on the river. Here again Scotch hospitality appeared in all its exuberance; and a delightful accompaniment of it was the exquisitely beautiful scenery on which our eyes feasted as we approached Inveraray. When we landed on the pier, we were courteously received by the Duke of Argyll's chamberlain, who guided us to the Castle. At the lodge, by which we entered the park, we had the honour of being introduced to a venerable descendant of Rob Roy, who resided there in the Duke's service. Having touched my hat to him, we cordially shook hands, and I then expressed to the old man the pleasure I had in making the personal acquaintance of one whose ancestor had played so stirring a part in Scottish history. On our arrival at the entrance to the Castle we were met by the Duke, who received us most graciously. Another circumstance then occurred, which much impressed us as we reflected on the relations which existed in former times between M'Callum More and Rob Roy M'Gregor. The Duke, as he stood on the doorsteps, pointed out to us a memorial of interest relating to the latter, which had been discovered not long previously in the cottage in which the fiery chieftain died, and which his Grace valued and carefully preserved. It consisted of the two small stones of a quern or primitive Scottish flour-mill, in which the family corn was ground by hand. They were placed one on either side of the entrance to the Castle. What scenes of the past was the sight of those little objects calculated to awaken in our minds! The bloody feuds of ancient days have happily ceased long ago, and Scotland has become peaceful, prosperous, and contented. Notwithstanding all the savage and protracted wars between England and Scotland in days gone by, what two members of this great United Kingdom are now bound together by stronger ties, the ties of goodwill and of mutual interest? Apologising for this digression which forced itself upon me, I have only further to mention the kind attention which the Duke showed to his visitors in personally conducting us through the principal apartments of the Castle, and pointing out those objects which he thought would most interest us; and he gave the history of the many valuable and historically interesting portraits which hung upon the walls. We finally bade adieu to his Grace, when I thanked him as best I could on behalf of the Institute for his courteous reception of its members. We left the Castle with regret, embarked in the *Columba*, and steamed right merrily back to Greenock, where some of our party left us and proceeded by rail to Glasgow; while the rest, including myself, remained on board until we landed at the Broomielaw.

After leaving Glasgow I proceeded to Keswick, where my friend, Mr. Snelus, of the West Cumberland Iron and Steel Works, had been good enough to secure apartments for me in the Keswick Hotel. At first I intended to stay there only for a day or two, but I was so charmed with the beautiful scenery surrounding Keswick, that I remained three weeks, and left with great regret. My quarters were excellent, and from Mr. Wilson, the worthy landlord, I received the greatest attention. I found him a highly intelligent, cultivated, and genial man, and possessing, moreover, no mean literary talent. I read with much pleasure an article by him in *Fraser's Magazine* on former social life in Cumberland, and other published papers also by him. He accompanied me in several drives amongst some of the finest scenery of the district, and pointed out to me every particular feature of interest. I thus saw much that escapes the attention of ordinary tourists. The Keswick Hotel is situated on high ground, just under Skiddaw, and commands on every side fine prospects of the adjacent mountains. I met also at Keswick an able and devoted geologist, Mr. Postlethwaite, to whom I felt greatly indebted for his kind attention. He has done good original work in geology, especially concerning the graptolites and trilobites of the district. Beautiful specimens of iron ore and other minerals of the district are procurable at Keswick at reasonable prices, and I did not fail to avail myself of the opportunity of adding to my collection. I noticed in certain of the mineral dealers' shops noble specimens of kidney ore, which struck me as remarkable for their deep black colour and bright lustre. But I found on inquiry that these peculiarities were due to a well-polished coating of black-lead!

I may remind you, gentlemen, that at this season, last year, I expressed my fervent hope that the gloom, which had so long previously hung over the iron and steel-making world, might soon disappear. That hope, I regret to say, has not been fulfilled. The spirit of gloom still hovers over us, and other spirits, also equally malignant, seem to have risen from "the vasty deep." Since we last met, I have read much on the subject of the prevailing trade depression, but have not yet had the opportunity of examining the evidence presented to the Royal Commission, presided over by the Earl of Iddesleigh. However, from all I have been able to gather, it appears to be generally admitted that over-production is the main cause of the evil in question. The disease, if I may be permitted so to designate it, is epidemic. It is not confined to Great Britain, but extends to every country where iron and steel are made on a great scale. Of the truth of that proposition, it is not necessary for me, before an audience like the present, to adduce any proof, for it must be patent to you all. When we consider the gigantic power of production in the matter of iron and steel, it would, indeed, excite surprise were over-production not to exist. When I saw the enormous resources of Scotland for the manufacture of steel, I was never more startled or more impressed; and when I reflected that Scotland not long ago made no steel, and that the mighty development of her steel industry had taken place within a few years, my astonishment was further increased. That development is still progressing, as is shown by the recent adoption of the basic Bessemer process at the Glengarnock Works, where it was in active operation when I visited those works during the Glasgow meeting of the Institute. Now let us consider the fact of the erection, within a comparatively short time, of vast steel works in the North of England and in Wales, and that of the opening of large basic steel works in South Staffordshire so recently as last year; and then, let me ask, can we be surprised there should be over-production? Besides, what has thus taken place in our own country has also occurred to a greater or less extent in Germany, Belgium, France, Austria, Russia, and especially in the United States of America. Can any doubt now remain as to the fact of over-production in the matter, at least, of steel? If the fact of over-production be established, then it follows that so long as it continues, there must be depression in the steel trade. But British steel-makers have a special enemy to contend against, and that is fierce competition from abroad, where workmen labour for a longer time and for less wages than our own. There are, however, unmistakable signs of growing discontent amongst foreign workmen on account of the comparative lowness of their wages and the greater length of their labour shifts. Are not these signs evident, from the recent serious and protracted riots in Belgium, even not yet ended, and which have led to such a deplorable destruction of property of enormous value? There seems to be a general rising tide of discontent, not only amongst the proletariat on the Continent of Europe, but also in many parts of the United States of America. Judging from the reports which I have read in *The Times*, concerning the remuneration of labour in Belgium, the condition of many working-men there seems very sad, inasmuch as they can barely procure the means of subsistence by the hardest of toil. Such men deserve commiseration, and deserve it all the more, because they have been excited to deeds of violence by the inflammatory harangues of heartless and atrocious scoundrels, banded together in secret organisation for the purpose of setting class against class and uprooting civilisation. It is time that all civilised nations should unite in one common determination, namely, that of extirpating such destructive vermin. Our kinsmen in the United States have, as was naturally to be expected from such an intelligent, energetic, and law-abiding people, shown Europe how to cope with these inhuman monsters. There has been no temporising in their case. They knew the nature of their enemy, and treated him as they would ferocious tigers. Their action was decided and sternly repressive, and certainly it was the most humane course to adopt. It was gunpowder against dynamite, and happily the former prevailed.

Owing to the cheap and rapid communication of intelligence throughout the world, what is done in one part of it is almost immediately made known through the press in every other. The rates of wages and hours of labour in one country soon become the topic of conversation amongst the workmen of another; and it seems, therefore, not improbable that the Belgian workmen, after having compared their own condition, with respect to remuneration and hours of labour, with that of their brethren in Great Britain, may have become more and more dissatisfied, and, in consequence, attempted at last to improve their position by agitation. However this may be, it is clear that should such agitation be successful, not only in Belgium but in other foreign countries, as is not unlikely hereafter, then our own iron and steel trade will have less to fear from foreign competition. Of course such a conclusion rests on the assumption that our own workmen will not imitate the example of their brethren in Belgium and elsewhere. It is to be hoped that, owing to the conciliatory plan which has been adopted here, differences between employers and employed may be found to be more and more easily capable of satisfactory and amicable arrangement. Under existing circumstances, it seems hardly possible that steel should ever be manufactured at less cost than at present. This, I think, is a pretty safe prediction; but I remember the surprise which I felt when Sir Henry Bessemer told me, on the 29th of October 1864, that, by running pig iron direct from the blast-furnace into his converter, he thought steel might be made for £4, 10s. per ton; and yet we have lived to see even finished rails of his steel now sold at a lower price.

The future of our supplies of iron ore is a subject of no small interest to members of the Institute. The Bilbao and other fine ores are being rapidly exhausted; and it is predicted that actual exhaustion is not far distant. Our secretary tells me that he has been informed by an American gentleman, thoroughly acquainted with the iron and steel trade, who has been scouring the world in search of suitable ores, that, in his opinion, such ores, before very long, are likely to become scarce, and, consequently, to fetch a higher price than at present. This is a somewhat startling announcement. But there are, doubtless, many unexplored localities in which it is probable good ore will be discovered. The cost of transit, however, and other local circumstances may, in some cases, render the ore unworkable on the ground of economy. I may mention a fact which my friend, Mr. Bauerman, has communicated to me, namely, that in recently visiting South America he saw in one locality enormous deposits of hæmatite, which extended over a long range. These deposits are as yet untouched, and access to the coast would be very expensive in the absence of roads, as is the case at present.

I have hitherto spoken only of the over-production of iron and steel. I will now venture to speak of the over-production of man. The surface of the earth is limited; but the human race is constantly increasing. Assuming that in the course of Nature nothing extraordinary will occur to check this increase, it may be concluded with absolute certainty that the time must come when the earth will be incapable of supporting the human race. That time may be remote, even in a geological sense; but eventually come it will. We are doing all we can to thwart the normal operations of Nature in preventing over-population; all our beneficent sanitary arrangements, our attempts to lessen the destruction of human life by famine in India, through irrigation, to stamp out Asiatic cholera and other plagues and pestilences to which flesh is heir, and to prolong human life in a thousand other ways, all tend to hasten the time when the earth shall no longer be able to yield sufficient food for the wants of man. You will be pleased to observe that I am stating what I conceive to be stubborn facts, and I assure you it is farthest from my intention to disparage the noble work of philanthropists. It has been computed that if the forests of North and South America were cut down, and the whole cultivable surface of that vast country were made subservient to the needs of man, it would be capable of supporting from two to three thousand millions of our race. Now you all know that the leaves of plants are the sole agents by which nature effects the decomposition of the carbonic acid, perpetually being exhaled by every breathing creature, and that, without their agency, the atmosphere would become poisonous and irrespirable. It may, therefore, be asked, whether if all the forests of the world had disappeared, and the whole available surface of the land been brought under cultivation, the grass or other crops which succeeded would be equivalent in decomposing action to the foliage of the preceding forests. I am unable to answer that question, but my impression is they would not.

What hereafter, in the fulness of time, will infallibly occur to man, if the course of Nature continue unchanged, and which there is no reason to doubt, is, it seems to me, what is being locally exemplified now. There is, unquestionably, local over-production of man, and hitherto the only remedy has been emigration. Look at the enormous Anglo-Saxon population distributed throughout the world, and then ask where Great Britain would have been without that source of relief? Emigration is a necessity, and though some politicians may sentimentalise over the wrongs of Ireland, and propose all kinds of panaceas for its tranquillisation, it is as necessary for that part of the Queen's dominions called Ireland, as it has been and is for the other part called Great Britain. We hear much about the Irishman being so wedded to his native soil that it breaks his heart to leave it. But leave it he must when it becomes impossible for him to exist upon it. Nature is stern and wholly unsympathetic. If a man builds his house on the side of a volcano, he must take the risk of being some day suddenly suffocated by a shower of pumice, or burnt alive by a fiery stream of lava. So if another man attempts to exist where Nature forbids, he must either quit the locality or starve. There is no conceivable alternative.

Permit me to digress for a moment or two, and say a word as to the cause of Irish wrongs. In an article which I wrote for the *Quarterly Review*, headed "Coal and Smoke," and which appeared in April 1866, I stated what follows: "Ireland is for the most part exclusively a pastoral country, and no pastoral country can become as rich and prosperous in a material sense as a country which, like Great Britain, possesses vast stores of coal, or in other words, of manufacturing power. It would seem that Irish wrongs are in part the result of a cruel theft which Nature herself committed at an extremely remote epoch; for there is reason to believe that coal was once deposited over a large part of Ireland, and afterwards almost wholly washed away, or, as geologists would say, removed by denudation. This is the conclusion arrived at by one of our ablest practical geologists, Mr. Jukes, Director of the Irish Geological Survey." Mr. Ruskin, and those who think like him, if there be any such, might regard this theft of Nature as a blessing, and not the reverse. It is, however, extremely probable that Irishmen would not be of the same opinion.

What I have just said concerning emigration, in which I have adduced the case of the Irish peasant solely for the purpose of illustration, and not for want of sympathy with him, is equally applicable to the British workman when he finds himself in a congested locality, where, owing to no fault of his own, he is the victim of circumstances beyond his control, and inevitable in the fluctuations of modern life, and is thereby unable to obtain profitable employment. What alternative has he but to become either a pauper, from which his soul revolts, or an emigrant to a country ready to welcome his advent, and provide amply for more than his actual necessities? Emigration is not now like the expatriation of former days. A home awaits him in our vast colonies, where he meets with his fellow-countrymen and enjoys all the blessings of civilised society; and where he has, moreover, the facility of quick and cheap communication with his relatives and friends at home. Interminable tracts of good land in healthy climates still lie barren, of which he may secure a portion at a merely nominal price and erect a comfortable dwelling thereon. This land, it is true, may in some cases require more than tickling with a hoe to make it blossom into harvest, to use the well-known expression of my friend, the late Douglas Jerrold. It may need persevering labour, though not such as to overtax his strength. But what man, who is good for anything, fears honest work? To live in idleness is not the normal condition of man, nor is it the condition which most conduces to health and happiness. No men are less to be envied than the "mashers" of our time, who spend their days in the vain pursuit of phantasmic pleasures. Miserable creatures indeed are they, a curse to themselves and worse than useless to the world!

All men, it has been said, are born equal; but if by the word equal is meant of the same capacity, bodily as well as mental, no proposition is obviously more false, and none is more mischievous. It may sound well to the ears of shallow humanitarians, and be used by wily politicians to impose upon and flatter their too credulous hearers. Never before, I think, was quackery of every kind more rampant or men more apt to be misguided by the fine phrases of popular idols. What is the tendency of the belief in such a proposition as I have announced? There is but one answer, and that is—To prevent men of superior capacity from availing themselves of their natural powers, and sink them to the low level of monotonous mediocrity. Trade unions, founded with the object of raising subscriptions from their members, and so providing a common fund for the relief and assistance of such as may become incapacitated for work by sickness, or overtaken by adversity through no fault of their own, are truly beneficent institutions. But when they travel beyond, and say to this man, "Thou shalt not avail thyself of the powers God has given thee, however strongly thou mayest be prompted to do so, even with the sole object of benefiting thy wife and children;" and to another man, "Rest contented, friend, for whatever may be the superiority of the natural powers of some of thy fellows to thine own, thou shalt be protected, and be as well off in worldly circumstances as they are," then, I say, their action is as mischievous as it is unjust. It is destructive of individual liberty, and it has always surprised me that any intelligent men should be found willing to submit to restraint so galling and prejudicial to their welfare. It is this action on the part of trade unions that has often proved injurious to working men themselves, and blighting to the prosperity of the country. Charity possibly may have had some share in prompting the leaders to this course of action, and inspiring them with the hope that by lessening the amount of force capable of being developed by the abler class of workmen, they might proportionately diminish production, and so provide occupation for those who would not otherwise obtain it.

In conclusion, I have to apologise for having trespassed so long on your attention, and, I fear, tried your patience to the uttermost. If I have, inadvertently, touched on any question or uttered any expression justly deserving your censure, I sincerely regret it; and would willingly make the fullest amends in my power. I trust that before we meet again in the autumn the prospects of the iron and steel trade will be brighter than at present.

This year will be memorable from the fact of the assemblage in London of representative men from every part of the Queen's dominions, who have come to show, not only us, but the world, how vast and varied are the resources of the British Empire, and to afford us ocular proof of the fact. I think I may venture, on behalf of the Iron and Steel Institute, to promise those of our Colonial and Indian fellow-subjects who may wish to obtain information concerning our iron- and steel-producing power, every facility for doing so which the members of the Institute may be able to give.

I will end my Address with a prayer in which I feel sure all the members of the Institute will join, namely, that, if it please God, the ties which connect our Colonial and Indian fellow-subjects with ourselves may acquire ever-increasing strength, and that the British Empire may continue to exist unmutilated for many and many a generation to come.

NOTES.

Note 1, p. 8.

Fibrous Silica, p. 8.—In my volume on Iron and Steel published in 1864, p. 508, I expressed the following opinion :—"Fibrous silica in the blast furnace probably owes its origin to the oxidation of silicon, which is certainly separated in a greater or less degree under the same conditions as graphite. According to Devile, it is oxidised at a high temperature, even by carbonic oxide. If it be a product of the oxidation of silicon in any way, it occurs just where it might be expected, namely, where silicon is known to exist."

Note 2, p. 14.

Fung Shui.—"It is a modern superstition, which has a very firm hold on the people in all places and of all classes. The principle of it is this : that all genial life-giving influences come from the south, and all those of an evil deadening character from the north. They think that these influences proceed in as straight a line as possible ; and that if any high building be raised, it will divert the current from the places due north of it, and so injure the inhabitants in the direct line immediately beyond. On this account, they imagine that cuttings in hills and through graveyards would awaken the whole invisible fraternity, and produce most disastrous consequences. For the same reason, they think that high towers, telegraph-poles, railway-cuttings, and signals, would compel the good spirits to turn aside in all directions, and so throw everything into confusion."—*Journeys in North China, Manchuria, and Eastern Mongolia ; with some account of Corea.* By the Rev. Alexander Williamson, B.A., Agent of the National Bible Society of Scotland. London. 1870. Vol. i. pp. 15–16.

Sir I. **Lowthian Bell**, Bart., F.R.S., said that before proceeding further with the business of the morning it would be appropriate, and indeed indispensably necessary, to thank the President for the very interesting address which he had just delivered, and he proposed a vote of thanks to him accordingly.

Sir **Bernhard Samuelson**, Bart., M.P., F.R.S., in seconding the motion, said he supposed that in that room, at any rate on the occasion of any of their meetings, no address had ever been delivered which had dealt with so great a variety of topics as the address to which they had just listened. In regard to those portions of it which were cognate to the objects of the Institute, there could be no question whatever as to its merits. They had been of extraordinary interest, and formed a fit introduction to the business about to be brought before the meeting. But the President had followed in the wake of other scientific men, such as Professor Tyndall and Professor Huxley, in calling attention to subjects of more general interest, and he thought the members would agree with him in the opinion that it was desirable that they should, on occasions when such subjects might be properly introduced, hear the opinions of men of science on social questions. Whether the present time was one in which the topics which their President had brought before them might be considered with advantage was a question that admitted of no doubt, for they were passing through times when these questions were engaging the attention of all thoughtful men. But whether that was precisely the place where such objects should be discussed could only be left entirely to the good taste of their excellent President. He was sure the members would join Sir Lowthian Bell and himself in according a vote of thanks to the President for the important address which they had just heard.

The motion was carried by acclamation, and duly acknowledged by the President.

THE BESSEMER MEDAL.

The President then said that his next pleasing duty was to present the Bessemer Medal to their good friend Mr. Edward Williams, from whom at all times, especially on his visits to Dowlais and Middlesbrough he had himself received the kindest attention. Mr. Williams was well known to nearly all, if not all, the members of the Institute. With his characteristic dash of impetuosity, he was at the same time known as pre-eminently a genial man, having an excellent heart, and being disposed to do an act of kindness to everybody. He had, however, chiefly distinguished himself by the great interest which he had taken in the early development of the Bessemer process. The President would ask Sir Henry Bessemer to say something upon that subject. Mr. Williams had also shown from the earliest period of the foundation of the Institute the liveliest possible interest in its success, and had unremittingly devoted his best efforts to secure that object. He would call upon Mr. Williams' son to receive the medal for his father, but before doing so he would respectfully invite Sir Henry Bessemer to say something on the subject, which would be much better worth hearing than anything that he himself could say.

Sir HENRY BESSEMER said it was with great pleasure he addressed a few words to the meeting with reference to the recipient of the medal about to be presented. It was a great gratification to him to find that the Council had awarded the medal this year to Mr. Williams. Although Mr. Williams did not stand before them as having made any brilliant discovery, he was known to them all as one of the best practical iron-makers living. The energy and the perseverance with which he had conducted the affairs that had come under his attention, whether for others or for himself, were such as to do infinite credit to him as a practical man, and it was to practical men that the Institute owed most in the development of the iron trade. As an instance of the energy displayed by Mr. Williams he might mention the fact that it was thirty years (less three months) ago since he first made that gentleman's acquaintance. He had then just read his paper at Cheltenham with which the members were well acquainted. That was on a Tuesday. On the Wednesday the paper appeared in the *Times*, and it was read at the Dowlais Works about mid-day by Mr. Williams, and also by Mr. Edward Riley, who was then also employed at Dowlais. They were both immensely attracted by the novel proposition, and they were so practical and so scientific that they said to themselves, "Surely this is either an enormous fallacy or a great fact; let us try it." They accordingly set to work and erected a small brick converter, turned on their low pressure blast, used the metal as it ran from the furnace, so that by the Friday they had a blow, and by Saturday afternoon Mr. Edward Williams had rolled a bar of iron with no other instruction than that which he had received from the paper read by Sir Henry at Cheltenham. Happily a piece of that bar had been preserved, which Sir Henry had had the honour of presenting to the Institute, and it was now at the offices in Victoria Mansions, where he hoped it would long remain, an honour to the practical man who had produced it. He need not dwell any further on the merits of a gentleman so well known to them all: he would only add that he greatly regretted that ill-health prevented Mr. Williams from being present, but hoped that he would soon be restored to convalescence.*

The PRESIDENT then formally handed the medal to Mr. Illtyd Williams, as the representative of his father.

Mr. ILLTYD WILLIAMS said he desired to thank the Council of the Institute for the honour they had done to his father in awarding to him the Bessemer Medal, and the President and Sir Henry Bessemer for the kind words they had spoken. He very much regretted that it was impossible for his father to be present to thank them personally for the honour conferred on him, which he would have done much better than he (the speaker) could hope to do. He did not know that he need trouble the members with any further remarks, and he would only thank them again for their kind consideration of his father.

The following paper was then read:—

---

* Sir Henry Bessemer's hope has not been realised, Mr. Williams having died on the 9th of June. An obituary notice of the deceased gentleman will be found in the Appendix, p. 213.

ORIGIN AND PROGRESS OF THE MANUFACTURE OF TIN PLATES.

By Mr. PHILIP W. FLOWER, Neath.

> "Iron is the metal which is most easily destroyed; it lies open to the weakest dissolvents; even common water attacks it with success. In order to protect finished iron from rust, it has been usual to cover it with different coatings: some are oiled—the most precious are gilded—some are bronzed; it has been thought of covering the commonest with tin."—De Reaumur, 1725.

An intimate knowledge of the art which is known as the manufacture of tin plates dates back to a period which is beyond the records of metallurgical history; but the trade is known to have been of German origin, and to have existed in Bohemia for many years prior to 1620.

The existence of tin-coated iron vessels, however, dates back to the days of Pliny (A.D. 23), and this historian expressed surprise (as many people do to-day) that the *weight* of the iron was so slightly increased by the coating of tin. Aristotle, writing long before Pliny, was "exercised" by the low degree of heat at which Celtic tin would melt, and by the fact that molten tin appeared to break through paper rather by weight than heat. It is further on record that Alexander the Great, when in India, received a present of 100 talents of Ferrum Candidum or white iron.

The tin which was required in these early times for the coating of iron and other useful purposes, was no doubt obtained from the Phœnicians trading out of Tyre, who, by their well-known cleverness in navigation and astronomy, were able to cross the Bay of Biscay, and thus to control the trade which undoubtedly existed between Syria and Cornwall 300 B.C.

It has been well said of the Phœnicians that they were the most commercial people of all antiquity; they affected no empire but that of the sea, and seemed to aim at nothing but the peaceable enjoyment of their trade; and this they extended to all the known parts they could reach, both within and without the Straits of Gibraltar.

Herodotus, writing 450 B.C., explains that he was personally unacquainted with the Cassiterides whence our *tin* comes, and further that he was unable to record with certainty whence gold was obtained, but says he had been told that the Arimaspians, a one-eyed people, steal the gold from the griffins.

Diodorus Siculus, however, states plainly that the tin was obtained from Bolerion (Land's End), and he refers to the hospitality of the inhabitants, who were, he says, civilised by intercourse with foreign merchants; and he describes the very nature of the mining operations and the shape of the ingots as "knuckle-bones."

This narrative is strangely confirmed by the dredging up of a knuckle-bone ingot of tin at Falmouth in 1811, following which Major-General Sir Henry James, F.R.S., published in the *Archæological Journal*, No. 111, 1871, a very clever illustration which shows at a glance how suitable the shape was for conveyance on horseback. It is most probable that the tin was cast in this shape to serve the purposes of the Greeks trading out of Marseilles; for the custom of these traders was to coast the metal from Ictis, St. Michael's Mount, to Hythe or Deal, whence they crossed the Channel to France, from whence the tin was conveyed on horseback in thirty days to the mouth of the River Rhone.

Strabo, another of the old historians, also refers to the Cassiterides, but, although celebrated for his geography, can scarcely, I think, be complimented upon his geographical knowledge of these islands. He says:—"The Cassiterides are ten in number, and lie near each other in the ocean towards the north from the haven of the Artabi."

As the coating of cast iron, however, does not properly form part of the subject upon which I have the honour to address you, I will return at once to the history of tin plate manufacture in Germany.

I have already stated that the manufacture of tin plates existed in Bohemia *prior* to 1620, and this circumstance is proved by the fact that in the year 1620 the reigning Duke of Saxony sent people to Bohemia to obtain such information as would enable him to "fix" the manufacture in his own dominions. The medium employed to discover the trade secrets was a Roman Catholic priest disguised as a Lutheran; and the adventure was so successful, that when Andrew Yarranton visited Saxony in 1665, he found the establishments to be so numerous and the trade so very profitable that several brave cities had been raised by the riches therefrom.

The situation selected by the priest and by his master, the Grand Duke, for their tinworks, appears to have been particularly well chosen, and upon business principles, for iron, tin, and charcoal were to be found upon the spot, where there was also water-power and facilities for conveyance of all materials by water.

Perhaps it was enterprise which gave Saxony the trade, but possibly it was only an early example of the necessity which sometimes compels ironmasters to "develop" their market.

The manufacture, however, must have been very tedious, for all the plates had to be hammered out by hand to substance, and in the absence of acid they had to be soaked in sour barley-water, which took days to accomplish what is done in a few minutes by vitriol. The "system" then in vogue was for the proprietor to furnish all the materials and for the master to provide labour and superintend the manufacture for so much per box of 300 sheets.

The tin plates, when completely finished, were packed in casks or barrels of about 140 lbs. Prague weight, each containing 300 sheets 12 × 9, or 150 sheets of 18 × 12, which were selling in 1760 at 60 francs per cask upon the spot, and the workmen said that the profit was enormous. Delivery to Leipzig was made across the Erzgebirge mountains by pack-animals, or by sledges to the banks of the Elbe; it was found *cheaper* to sledge them over the snow.

Between the years 1650 and 1680 two unsuccessful attempts were made to start the trade in France, viz., one at Chenesey in Franche-Comte, and the other at Beaumont la Ferrière, in Nivernois.

These attempts were organised under the fostering care of Jean Baptiste Colbert, the eminent Minister of Louis Quatorze, who was assisted by the amiable and intelligent M. de Reaumur, who, like Mr. Yarranton, had made a purposed visit to Germany.

M. de Reaumur explains his want of success by saying: "The works subsisted for several years, but these valuable workmen, not finding themselves supported by the intelligence and protection to which the trade owed its origin, had no success and withdrew." The same author, writing in 1725, has left us the following quaint observations upon what is now known as the pickling process:—"Our sheets of black-plate are covered with a shell—a slight coat of half vitrified iron, on which acids have little or no effect. It is very likely that this coat, which is neither flexible nor malleable, has infinite cracks which give way to the acid; first it digs at the iron in a right line, but afterwards it attacks it on the side, enters under the shell, and removes the shell as soon as it has gnawed the iron to which it was attached."

Before passing on from Germany and France to English details, I desire shortly to bring under notice a work entitled "England's Improvements by Sea and Land," published by Andrew Yarranton, Gentleman, London, 1677, to whom *alone* we are indebted for a reliable narrative of the circumstances which assisted and promoted the introduction of the tin plate trade into England. Dove, in his "Elements of Political Science," says that Yarranton was the first man in England who saw and said that peace was better than war; that trade was better than plunder; that honest industry was better than martial greatness; and that the best occupation for a Government was to secure prosperity at home and to let other nations alone.

Yarranton informs us that in the year 1665, the English metal trade was passing through a period of severe depression, the use of pit-coal for ironmaking had not then been discovered, charcoal had become excessively scarce, and English-made iron was undersold by importations from Sweden, Germany, and France.

Swedish bars were at £13, and French nail-rods at £15 per ton in London. The price of tin had fallen from £100 to £60, and the tin-miners of Cornwall were in great distress, some of the workmen being positively in want of food and sustenance. It was no doubt under pressure of these *combined* circumstances that the happy thought occurred of introducing a new manufacture which it was hoped would bring relief to *both* trades. The material was already well known in this country, as London was, in and prior to 1665, exclusively supplied with German tin plates, which were imported from Hamburg.

Mr. Yarranton having brought his idea under the notice of persons of influence, a "Syndicate" was formed headed by Sir Walter Kirkham Blount, Baronet, to defray the expenses, and a well-arranged party inclusive of an expert in iron, and an interpreter who was accustomed to deal in German tin-plates, travelled from London, *via* Hamburg and Leipzig, to Dresden, where, contrary to expectation, they were well received, and allowed to examine the manufacture and the works.

Mr. Yarranton and his friends having, as they judged, sufficiently ascertained the whole art of tinning, the party returned to England, and the several persons concerned in the affair made trial of the process by experimentally tinning small quantities of plates, which, Yarranton tells us, were very much approved by the London and Worcester tinmen, who found them to be more "pliable" than the German sheets.

Arrangements were then made for establishing the manufacture upon a permanent footing in the village of Pontypool, under the auspices of the Hanbury family; but so soon as it was known in London that the affair was successful, all progress was stopped by the following strange incident:—A patent for the manufacture of tinned sheets was applied for, and, by means of favour at Court, was granted by William and Mary to an impostor named Edmond Hemming, A.D. 1691 (No. 282).

The patent, *per se*, was not of much value to Hemming, for Yarranton tells us that he could not produce one single plate fit for use, but the *moral effect* of the patent was sufficient to prevent the manufacture elsewhere, and thus it happened that nothing further was done in the matter for a period of forty years. In the year 1720, however, memorable as the year of the South Sea Bubble, the manufacture was once more started at Pontypool under the management of Major John Hanbury, and from there it passed to Caerleon, Kidwelly, Melingriffith, Ynisygerwn, and other places, as a *dependency* of then existing water-driven charcoal forges.

John, the eldest son and heir of Capel Hanbury, usually known as Major Hanbury, was born in 1664, and chose the profession of a barrister, but Coxe, in his "Historical Tour," relates that he one day told Mr. Jones of Llanarth, that having read "Coke upon Littleton" as far as Tenant in Dower, he concluded that it would be more for his advantage to turn his attention to mines and forges.

Monmouthshire may fairly claim to be the pioneer county of the iron and tin plate trade in Wales.

The Rev. Mr. Britton, writing in 1810, explains that the attention of the county was first excited to this lucrative branch of manufacture in the reign of Queen Elizabeth, 1558–1603, and made rapid progress. It was then checked by the troubles in the time of Charles the First, 1625–1649; and when agriculture came in again the forests were neglected, and large herds of goats destroyed the woods, which were essential for charcoal-burning. However, following the introduction of pit-coal for ironmaking, a sudden renewal of the works took place in 1770, and in that year there were eight charcoal forges existing, five of which were owned by Harford, Partridge & Co., viz., at Machen, Gelliwastad, Bassaleg, Caerleon, and Monmouth, Pontypool forge and tinworks, owned by G. C. Leigh, Esq., tin-mills at Rogerston and Caerleon, and charcoal wireworks and forges at Tintern and Abercarne.

The modern process of manufacture being now so well understood, I think it will be sufficient for me, generally, to record the approximate dates of the several important improvements which have been adopted since a knowledge of the art came to England in 1665; but as the introduction of steel is of such recent date, and has so completely revolutionised the trade, I propose to examine this feature specially.

In 1728, the introduction of sheet iron *rolling* by Major Hanbury, of Pontypool, which was described at that period as the "art of expanding bars by compressing cylinders."

In 1745, the employment of a grease pot to warm and prepare the iron for receiving a coating of tin.

About 1770, the application of pit-coal as a substitute for charcoal in the manufacture of iron.

In 1806, the substitution of vitriol for barley-meal as a medium for pickling purposes.

In 1807, Mr. Watkin George, of Pontypool, introduced the dandy fire as a preliminary process for the refinery, and the brick hollow fire as a substitute for balling.

In 1829, Mr. Thomas Morgan introduced cast iron annealing pots, as a substitute for annealing in an open furnace.

About 1849, the black pickling by vitriol was introduced as a substitute for scaling.

In 1866, patent rolling, so called, of the tin plates as they leave the tin pot was introduced by Mr. Edmund Morewood, of London, and Mr. John Saunders, of Kidderminster.

In 1874, pickling machines were generally introduced as a substitute for hand labour.

In 1875, the introduction of Siemens soft steel as a substitute for charcoal iron.

In 1880, the adaptation of Bessemer steel as an equivalent for puddled bar iron.

In 1883, the introduction of basic steel blooms from Middlesbrough in competition with Bessemer bars.

The abandonment of the charcoal and puddling forges in South Wales appears to have been strangely foreseen by the poet Dryden, who (in connection with the Iron Age) wrote as follows:—

"And DOUBLE death did wretched man invade;
By STEEL assaulted and by gold betrayed."

OPEN-HEARTH SIEMENS STEEL.

The employment of Siemens steel bars as a substitute for charcoal bar iron, marks a period which must always remain memorable in the history of the tin plate trade. The object of the charcoal forgemaster has been, for ages, to produce an iron which would fold and stamp and bend to meet the severest tests of tin plate conversion, and up to 1875 he had been able to hold his own under all competing circumstances. It was the pride and pleasure of his life to boast that the open-hearth refinery system had stood unchallenged since the time of the Romans, and he believed that the manufacture of charcoal forged iron was placed beyond the risk of ordinary trades.

I think that he was right upon the question of quality, for it can never be fairly said that steel superseded charcoal iron upon its merits as a metal, for charcoal iron has made and can still make *deeper* stampings than steel. Sir William Siemens worked for years to produce a competing material, and eventually, by *cost*, he mastered the situation. The introduction of open-hearth steel as the foundation for charcoal tin plates, dates, commercially, from 1875, when the Landore Works were under the direct management of Dr. C. W. Siemens. The product of the open-hearth process, which is, in fact, homogeneous ingot iron, was for some unknown reason classed by the trade as "soft steel," and I believe that this fact delayed its adaptation for tin plate purposes.

The quality of steel (as formerly understood) was perhaps of all materials the most unsuitable for tin plate purposes, being harsh, springy, and brittle, instead of soft and tough. Thus it happened that a strong prejudice at first existed against the new material, which was regarded both by buyer and seller as a cheap substitute for honest iron. The competition thus created was of great disadvantage to the charcoal forgemasters, as it placed a material at the command of cheap sellers, which enabled them to interfere with a trade which had been previously controlled by the charcoal forges.

The *surface* of the steel tin plates was always found to be sufficiently smooth and good, but violent and apparently capricious variations in toughness caused the plates to be unfavourably graded by experienced dealers, and the trade for several years had to be forced at a lower price than for charcoal. This preliminary irregularity, however, was gradually surmounted, and as gradually the trade expanded, until in 1880 the Landore Company was sending out 600 tons of bars weekly. The successful manufacture at Landore created a revival of the Elba Works, near Swansea, about 1878, which was followed by the construction of ten new furnaces in South Wales.

Swansea Tin Plate Co., .	2	furnaces,	Llanelly,	1879.
Birchgrove Steel Co., .	2	„	Swansea Valley,	1880.
„ „ . .	2	„	Cwmbwrla,	1882.
Leach, Flower, & Co., .	2	„	Neath,	1883.
John S. Tregoning & Co.,	2	„	Llanelly,	1885.

The three important advantages which are claimed from the employment of steel may be stated as follows:—

1. Economy in the waste which results from the conversion of bar iron into black-plate.

2. A reduction in the percentage of waster tin plates.

3. A reduction in the weight of coating metal, resulting from the smoother surface of steel black-plate.

It will be evident that when black-plate can be made to go forward to market at £12 per ton, instead of backwards to the forge at 40s., that this first consideration was important.

The saving upon tin, however, is not such a certainty as may at first sight be supposed. For the purposes of a provision canister it is sufficient that the iron should be suitably coated to protect the contents; but for heavy stamped ware and for planishing work, the iron must be sufficiently well coated to resist years of hard usage.

It has been a matter of general surprise that a use could be *so quickly* found for so large a quantity of this new material, but it strangely happened that concurrently with the introduction of steel came the general adaptation of stamping machinery from New York, which enabled the tinsmiths to produce *seamless* covers and boxes at one blow, and thus it happened that best plates took the place of the poorer material which was *formerly* employed for soldering work.

Description of the Siemens Open-Hearth Process.

The furnace itself, which may be roughly described as a punt-shaped bath, is constructed of cast iron shell plates lined with silica fire-bricks, and the bottom is formed by a thick coating of fused silica sand. A convenient bath measures 9 ft. × 15 ft., and holds about ten tons of molten metal, and remains under heat for a period of thirty weeks, when a fourteen days' stop is necessary for cooling, repair, and re-heating. The gas (for heating), which is manufactured outside of the cast-house, is introduced by means of ports situated above the metal, and flows in and out of the furnace by means of valves. The heat is created by a combination of gas with heated air, which produces an initial temperature of nearly 4000 degrees, the flames of combustion afterwards retiring at nearly 3000 degrees (Fahrenheit).

The foundation of the ingots is hematite iron, which is selected as containing the smallest percentage of phosphorus and sulphur which is to be found in English pig iron. The disadvantage of phosphorus is to render the metal brittle when cold, whereas extreme toughness when cold is the quality desired. As pig iron, of itself, is slow in coming to "nature," it is found desirable to add a certain percentage of steel scrap, which enables a larger production, but brings no advantage to quality. The pig iron is charged upon the bottom of the furnace, and the scrap is placed above it, and principally upon the sides, so as to catch the strongest heat.

After remaining for about three hours under heat, the metal becomes liquefied and begins to bubble; the melter then throws in a few cwts. of rich Spanish ore. The result of this operation is that the ore eats up the carbon, which it is necessary to remove, and causes the silicon to be eliminated by the oxidation which is set up by agitation of the metal. Additional quantities of ore are added over the next three hours, which eventually reduce the carbon and silicon to such a point that the metal begins to boil violently all over. This ebullition continues for three or four hours, during which period the carbonic oxide gas blows off from the face of the metal like candles or jets of gas, until the iron ore having calmed down the fury of the carbon, the mass of molten metal becomes quiescent. The wear and tear of the furnace is refurnished daily by the employment of well-dried silica sand.

When the metal has ceased to produce carbonic oxide flames, it is the duty of the melter to ladle out a sample, which, after being cooled in water, is tested roughly by hammering, and subsequently in the laboratory. In the laboratory the sample is drilled, and the drillings when weighed are placed in a glass tube, mixed with diluted nitric acid, and boiled until brown fumes appear. When the brown fumes change into white, and by the colour which then appears (viewed under advantageous circumstances), the chemist is able to say whether the metal, then in the furnace, is higher or lower in carbon than the standard test with which it is compared.

If too much carbon is found to be present, the melter throws in a little more ore, and subsequently tests again. When the chemist announces that the charge is equal to standard, the order is passed for tapping the furnace.

As the molten metal passes down the shoot to the ladle, the second furnaceman throws in, at regular intervals, coarsely powered red-hot ferro-manganese, the effect of which is to destroy the "red-short" quality of the metal, rendering it ductile, and easily forged when hot. The destruction of carbon by the use of iron ore and the elimination of silicon creates a softness and toughness in the metal, which can be hardened or softened at will, by proper regulation of the carbon, and it is by this means that steel, or ingot iron, is rendered specially suitable for such a variety of purposes.

A desire has been from time to time expressed to *hasten* the operations of these furnaces; but *time* is apparently as necessary to deal with the subtle qualities of pig iron as it is for the secrets of the Doctor's art, or for the operations of the "Chef" in his department.

Experiments in this direction were made at Landore in 1872, with a view to obtaining an increased output from the furnaces by feeding them with *hot* metal from a cupola; but the idea was condemned and abandoned as a *needless extravagance*, and it was by preference wisely decided to increase the size and number of the furnaces, rather than to make unnecessary outlay upon cupolas, and, further, to avoid the needless charges for castings, labour, and fuel which such a "Dependency" would *permanently* involve.

Having successfully beaten off the almost continuous competition of twenty years, it seems to be probable that the open-hearth furnace as a triumph of brick work will remain for ages a monument to the memory of the illustrious Dr. Siemens, who was knighted in 1883, as in recognition (by the Qûeen) of his unexampled services over a lifetime which was devoted to the development of *useful* scientific inventions.

BESSEMER STEEL.

The efforts to introduce Bessemer steel for tin plate purposes were commenced about 1864, when experiments were made upon

Dowlais bars by the late Mr. Joshua Williams, who was at that time the managing partner of the Aberdulais Works. The first intention was to compete with *charcoal iron*, but the attempt had to be abandoned in consequence of apparently capricious variation in the toughness of the sheets. The bars would vary for softness within their own length, the substance of the bars would also vary, and hard bars would constantly smash up the old-world machinery which was then in use.

These endeavours to compete with high-priced charcoal iron having failed, competition ceased until Bessemer bars dropped to a price which permitted the use as a substitute for puddled bar iron.

It will be understood that as a material for canisters, and for similar work, that steel escapes the tests which are inevitable for a better class of trade.

For stamping purposes, and for the higher grades of tinsmiths' work, every sheet must be a *certainty*, or the "result" becomes positively valueless, and the loss upon first cost of the material is frequently almost doubled by duty and transit charges.

For canister work, however, Bessemer steel is good enough, and a market has been opened out for at least 300,000 tons of bars yearly so long as suitable quality can be furnished at about the cost of home-made puddled iron.

It has been thought that steel tin plates should be able to command a better price than iron *because* they are steel, but this is not the case, as it is the *package* which rules the value of the raw material. It will be well understood that the packer cannot afford to pay a higher price for his package, whether of steel or iron, unless he can in his turn obtain a higher price for his vegetables and oysters, and this condition being obviously impossible, it becomes apparent that the employment of Bessemer steel for tin plate purposes becomes a question of price.

The "practice" which is in ordinary use for testing the relative tensile strengths of Siemens' and Bessemer steel *en masse* has no importance for tin plate purposes, where every sheet, *i.e. every pound of metal*, is compelled to meet or fail to meet the practical tests of conversion.

To illustrate the great importance to packers of reliable quality, it has recently come to notice that 20 × 10 plates ex Bessemer steel have failed to give the same good results for the covers and bottoms of petroleum drums as were formerly obtained from charcoal and best coke tin plates, and the "oil trade" has fallen back upon Siemens'.

The consumption for this purpose is enormous, and the consequences for the moment were most disastrous.

Many of the cases containing these drums were found to be so leaky that they were rejected by the ship; and the shipmaster reported a leakage so considerable from the cases on board that oil could be pumped up from the bilge.

An exhaustive examination of the matter established the fact that the plate which bent satisfactorily lengthwise would not stand the same test across the sheet.

A further illustration of capriciousness is to be found in the terne plates, which are so largely employed for roofing purposes in U.S.A.

Unless the sheets will fold satisfactorily *both* ways, the *joints*, when exposed to the subtle effects of the atmosphere, are liable to become ripped like paper by a paper knife.

Apart from theory and apart from an analysis (whether mechanical or otherwise), the fact that Siemens tin plates command a higher price than Bessemer upon all our markets, serves to establish the opinion of the world upon the relative value of these competing metals for tin plate purposes.

It cannot, nevertheless, be fairly reasoned that the experience of tin plate manufacturers is a guide for *heavier* trades; for probably no other manufacture can be named which compels every pound of metal to be brought beneath the relentless examination of the stamping press.

The following table will very briefly explain the actual progress, over more than 100 years, of this *now* important manufacture, consuming annually 460,000 tons of British iron and steel, which would be absolutely valueless for similar purposes if it were not for the protection which the coating affords.

It will be noted that so long as water wheels were a necessity for tin plate manufacture, the trade was naturally limited; but when steam power became available, the trade gradually expanded, particularly in Glamorganshire, which county still maintains its position as the leading centre of this industry.

Works existing in	1750.	1800.	1825.	1850.	1860.	1865.	1870.	1875.	1885.
Glamorganshire . .	...	2	4	8	12	15	19	27	44
Monmouthshire . .	2	4	6	11	12	12	15	16	20
Carmarthenshire. .	2	2	2	3	4	5	8	14	17
Staffordshire . . .	...	...	1	7	7	8	9	9	6
Worcestershire . .	...	...	1	2	2	3	3	3	2
Gloucestershire . .	...	...	1	1	1	1	1	1	2
Scotland	...	...	...	...	...	1	1	1	2
Herefordshire. . .	...	1	1	1	1	1	1	1	1
Flintshire	...	...	...	...	...	...	1	2	1
Cumberland . . .	...	...	...	1	1	1	1	1	1
Total works .	4	9	16	34	40	47	59	75	96

Estimate of 1884 Production.	320 Mills.	One Mill.
Per annum of thirteen months . .	6,896,300	21,550
,, month of four weeks. . . .	530,461	1,658
,, week of six days	132,615	414
,, day of twenty-four hours . . .	22,102	69

The estimated output of 21,550 boxes per mill per annum is based upon the combined *average* of returns made to the Board of Trade, and of payments to the Swansea Association.

Table No. 1 (in the Appendix) will show that the production of 1885 was 7,130,000 boxes, of which 5,230,000 boxes were taken for export, and 1,850,000 for home consumption.

Table No. 2 will show the countries to which export was made.

The improved methods of converting tin plates for useful purposes present a feature of special interest for those who are engaged in the trade, but would scarcely, I think, form a suitable subject for this paper.

In former days *tin kettles* were almost a monopoly of the gipsies' caravan, and the soldered-up tin canisters *then* in use were of the roughest character; but modern packages are the perfection of neatness and strength; and the almost endless variety of handsomely-finished, planished, stamped, and seamless articles which are so cleverly manufactured in America, and at Stourport in this country (from American tools), will explain to the uninitiated how it happens that tin ware is so much better understood and appreciated in the States.

The increased production, which is so plainly indicated since 1865, has no doubt been called for by the increased requirements for packing purposes upon all our markets, and has been particularly stimulated by the development of the U.S.A. trade in what are termed canned provisions and petroleum.

It is a strange caprice of Nature which has granted to America almost a monopoly of that valuable product, which thus enables the West to grow rich by selling ready-made light to the *East*, herself the Mother of Light.

If we take it that three-fourths of the entire production is employed for canister purposes, 3,000,000 boxes would produce 875,000,000 of 1-lb. canisters. By means of these canisters Europe receives largely of beef from the Western Prairies, salmon (in shiploads) from Oregon, mutton from the plains of Australia, fruit of all sorts from California, lobsters from Boston and Nova Scotia, oysters and peaches from Baltimore, sardines and green peas from France, pine-apples from Mauritius, apricots from Lisbon, milk from Switzerland, jams from Tasmania, and many other products of foreign soil, which complete the list of what the French have termed *conserves alimentaires.*

I will not refer in detail to the valuable *export* trade which has been created by these packages; but I think I have said enough to prove that tin canisters are a necessity of modern civilisation, and that the tin plate masters, like the old Phœnicians, administer to the luxuries and necessities of mankind.

While looking backward, as we can do with pride, to the almost revolutionary improvements which have marked the progress of this generation, and while looking forward, as we may do with confidence, to future developments under the fostering care of this distinguished Institute, we should not, I think, forget that the art of metal-working is not of *recent* date, but, on the contrary, had been carried to a high point of perfection at an early period of our history, as may be well understood from Homer's description of the very high art which was at Vulcan's command when "practising" in Greece almost two thousand five hundred years before the date of the Christian era.

"And first a shield he fashioned, vast and strong,
With rich adornment; circled with a rim,
And on its surface many a rare design
Of curious art his practised skill has wrought.
Thereon were figured earth, and sky, and sea,
The ever-circling sun and full-orbed moon,
And all the signs that crown the vault of heaven."

Table to show Production, Export, and Home Consumption of Tin Plates for Two Years ending 31st Dec. 1884 *and* 1885.

1st January to 31st December.	1885.	1884.
Exported from Liverpool	2,436,449	2,802,739
,, ,, London	427,298	426,968
,, ,, Swansea	1,809,166	1,311,665
,, ,, Bristol	455,830	223,883
,, ,, Newport and Cardiff . . .	41,833	280,914
,, ,, Glasgow	5,717	4,331
,, ,, Southampton and Weymouth .	45,067	60,251
,, ,, Hull	7,218	7,826
,, ,, Newcastle	1,958	2,424
,, ,, Newhaven		
Home Consumption	1,850,000	1,832,326
Stock at all Ports 31st December	293,244	241,880
Boxes . . .	7,373,780	7,195,207

	1885.	1884.
Stock 1st January	241,800	299,207
Production of 1884 *ex* 320 mills, each producing 21,550 boxes per annum	...	6,896,000
Production of 1885	7,131,900	
Boxes . . .	7,373,780	7,195,207

Table to show the Distribution of Tin Plates for the Two Years ending 31st December 1884 *and* 1885.

1st January to 31st December.	1884.	1885.
United States Ports	3,572,782	3,776,877
Canada and B. N. America	356,933	309,465
Mediterranean and Black Sea	298,142	255,312
Holland, Germany, Belgium	202,198	222,732
Norway, Sweden, Baltic	144,549	125,445
China and East Indies	123,324	93,972
France and Switzerland	112,502	100,560
Australia, Tasmania, New Zealand	106,914	137,918
Spain and Portugal	93,116	93,572
Central and South America	82,111	88,663
West Indies	14,930	12,893
Cape, Ceylon, and Mauritius	7,763	5,769
Africa and Outside Islands	5,465	3,404
Unclassed	272	3,954
Boxes . . .	5,121,001	5,230,536

DISCUSSION.

The **President** said that the subject of the tin-plate manufacture was one of extreme interest in many respects. There was no work of the kind that he had seen which had pleased him so much as that of his friend Mr. Flower, and he had always been extremely grateful to him for his uniform kindness in permitting him to inspect his works, and giving him all the information he required for scientific purposes. He was sure they would unanimously agree that Mr. Flower deserved their best thanks, and he proposed a vote of thanks to him accordingly.

The proposed vote of thanks having been accorded by acclamation,

Sir **Henry Bessemer**, F.R.S., said he wished to make one or two remarks on this very interesting paper. As the subject had been treated historically, he thought that any historical error that might have crept in called for rectification, and it was upon that ground only that he should trouble them with any remarks. The author stated that in 1875 the introduction of soft steel as a substitute for charcoal iron took place. With reference to that, he might mention that the first steel tin plates ever made in this country, to his knowledge, were made of Bessemer steel about September 14, 1856, or nearly thirty years ago. At that time Messrs. Philips & Smith, large tin-plate manufacturers at Llanelly, visited his experimental works in London. They were so satisfied that homogeneous metal produced by blowing cast iron was a suitable material for tin plates, that although his invention was then in a very imperfect state, they took a license from him to make 6000 tons a year at 10s. a ton, and paid him £3000. They made several very excellent steel tin plates, but his invention not being then in a perfect state, the manufacture lapsed for the time. When he was succeeding far better he invited them again to go into the matter, but they said, "Oh dear no, we shall never touch the material." He then repurchased for £1000 the license that he had sold to them, lest at some future time their cheap license should interfere with other manufacturers. A few years afterwards he induced a manufacturer in Birmingham to make some tin plates of his material, and a number of articles were made as specimens, to see what could be done. Many of those had become distributed among friends, but he happened still to have one vessel of tin plate made of his metal which was among the samples that he had had the honour to present to the Institute. When looking up very old samples in a lumber-room, he found several vessels that had been worked up by the process of spinning from his thin sheet metal, but these plates happened to be untinned, and having become rusty, they were thrown aside. He could show them pretty easily what they were like. The rust was easily got off, and one of them, which he now held in his hand, was made from a flat sheet of thin steel spun in the cold state on the lathe. They were exhibited in the International Exhibition in 1862, about ten years before Dr. Siemens' steel was introduced, according to the account given in the paper, and about twenty years before he (Sir Henry Bessemer) was credited with having introduced Bessemer metal for the manufacture of tin plates. He wished them to look at the shape of the vase exhibited, and they would see a flat plate of 11 inches in diameter, which was simply made to spin in a lathe with a blunt tool pressing against it until it had been gradually pushed into its present extraordinary shape. One portion of the plate, which was originally about 11 inches in diameter, was now reduced to 3, without showing any crack or flaw. He had another much more extraordinary sample, viz., a cylindrical vessel of great depth. Twenty-four years ago it was spun by a Birmingham manufacturer out of an 11-inch Bessemer metal plate, and in that cold operation of spinning it had become 8½ inches deep. The metal plate, which was only 11 inches in diameter, had stretched to 19 inches, and the periphery had at the same time been reduced from 11 inches to 2½ in diameter, and all that sliding of particle over particle known as the flow of solids had taken place without the slightest sign of fracture in any part. There was also another plate of 11 inches diameter which had been spun into an extraordinary shape, showing great contraction of one part and expansion of the other;

and he thought that few persons could look at these samples without being impressed with the fact that such a metal was in every way fit for stamping—that it could, in fact, be wrought into a variety of extraordinary forms, compressing in one part, and elongating in another, without fracture. Speaking of Bessemer steel, the author said, "For canister-work, however, Bessemer steel is good enough," and it was added that in 1880 the adaptation of Bessemer steel occurred "as an equivalent for puddled bar-iron." Puddled bar-iron was not a material from which the specimens he had just exhibited could be made, and he left it to the judgment of the meeting whether his metal was not an excellent substitute for charcoal iron, and not for common puddle bar. He merely wished to say that the author was in error in crediting his metal with having been introduced so late as 1880, and giving Sir William Siemens a preference of fourteen or fifteen years, whereas he had really introduced it for the manufacture of tin plate before Sir William Siemens's process was a reality.

Mr. **James Riley** said he rose with a considerable amount of diffidence on this occasion, but he took it that when a paper went forth authoritatively from the Institute presuming to give an historic statement of the rise, origin, and progress of a manufacture, great care should be taken that all statements were accurate. He felt a considerable amount of delicacy, as would be readily understood, in calling attention to the statement with regard to the introduction of the open-hearth Siemens steel for tin-plate making. The reputation of the late Sir William Siemens was sufficiently well established not to require bolstering by inaccurate statements, and there were two very strong ones in the paper. In the first place, it was stated that "Sir William Siemens worked for years to produce a competing material, and eventually by cost he mastered the situation." "The introduction of open-hearth steel as the foundation for charcoal tin plates dates, commercially, from 1875, when the Landore Works were under the direct management of Dr. C. W. Siemens." Both those statements were inaccurate to some extent. Sir William Siemens naturally worked for the production of the material which was to be supplied for the manufacture of tin plates; but when that steel was first introduced into the market in South Wales it was not manufactured under the direct care, or authority, or guidance, nor even under the indirect guidance, of Dr. Siemens, except in so far as he was a director of the Landore Company. He had thought that Mr. Flower would have well enough known the whole history of that introduction. He (Mr. Riley) happened at that time to have the management of the Landore Works. He was visited by Mr. John Parsons of the Llangenneck Works, the agent in this country of Messrs. Phelps, James, & Co. of New York, who had heard of some attempts that he had made to introduce for that purpose the mild steel which they were commencing to make at Landore. That gentleman took it up heartily; his firm in New York sent orders for plates to be made from open-hearth steel; and he gave those orders not only to the Llangenneck Works, but to the Morriston Tin-plate Works, and to many others in the Swansea and other neighbouring valleys. Samples were sent from time to time to Messrs. Leach & Flower of Neath, but on no occasion were they pronounced to be satisfactory by Mr. Flower or his firm, and Mr. Riley believed he was correct in stating that up to the time when he left Landore in 1878, Leach, Flower, & Co. had done nothing whatever in the use of the thin steel plates. Whether they had done so since or not he did not know. At all events, he thought it was sufficient for him to call attention to the inaccuracies in the paper, in justice to himself, for if any one should be credited with the later introduction of steel plates, he thought he might justly claim it. The work he did in regard to the manufacture in the first instance, and the introduction into the market in the next place, was well enough known to all the people in that district. He trusted they would excuse this personal explanation, but he could not let it pass in justice to himself.

Mr. **Edward Riley** said he could corroborate his namesake by saying that he was present at the Llanelly Works about 1875, and he then saw the steel plates they were using. He was asked to report upon the difficulties that were found in the manufacture of wrought iron, and he at that time recommended them to use steel. They were using it to a small extent, and the plates were in every way satisfactory. He could not say exactly whether it was in 1875, but it was somewhere thereabouts. He was with Mr.

Parsons, and spent two or three days at the works, and saw the steel plates, and he recommended that gentleman to give up the old process and use steel plates instead.

Mr. JOSIAH T. SMITH said that although no doubt Mr. Flower was not critically correct with respect to some statements, yet, looking at it broadly, commercially, and substantially, to a large extent the dates he had given with respect to Bessemer and Siemens steel might be considered as the points from which the tin-plate trade in South Wales began materially to alter its general mode of manufacture. When he read the paper, he thought that was the view the author wished them to take of it. What Mr. Riley had stated many present knew to be absolutely correct; and when Mr. Riley and others were engaged on the Siemens-Martin process in 1875, and forward, in making soft steel, they had practically no competition whatever with Bessemer steel makers. Sir Henry Bessemer stated—and no doubt correctly—that his firm at Sheffield had made considerable quantities of bars which had gone into the tin-plate manufacture; but, in reality, looking at the volume of the trade mentioned in the paper by Mr. Flower, it was almost of an experimental character, and he thought that if Sir Henry were asked what was the composition of the steel which was made by his process, he would not maintain that the samples before them were made of the ordinary English hematite iron, but would admit that to produce such results the charge from which the Bessemer steel had been made must have had a very considerable proportion of Swedish or analogous iron in it. The experience of all who had been for many years in the Bessemer trade was, that if they put into the converter iron of an extremely pure character, they could make a quality of steel which was quite suitable for any plate manufacture, or perhaps anything else that the Siemens-Martin process could produce. It had all come at last to a question of price, as Mr. Flower had put it. Up to within the last three or four years, all Bessemer steel-makers had had their plant fully engaged in making rails, and material of that kind, and it was only when the rail trade began to fall off, and the Bessemer makers had increased their capacity of make so enormously, that they began to look out for new markets; so that he thought he might say that practically

Bessemer steel was not introduced into the tin-plate trade of South Wales to any very large extent until about 1881 or 1882, at which time he, with others, began to try and invade the market; but they did so, he might say, very unsuccessfully. A large portion of the steel was all that could be desired, but a considerable portion of it was not so good as the manufacturers required. At that time they used spiegeleisen, and to a large extent it was due to the admixture of spiegeleisen in the process, instead of, as since, using the ferro-manganese, that they had been enabled to approach in quality in the Bessemer bars to what could be done with the Siemens bars using the same class of iron to begin with. His own experience in making both sorts of steel led him to acknowledge that he obtained better results for this purpose from the Siemens-Martin than from the Bessemer process; and while Sir Henry might feel, and all of them who had long been interested in the Bessemer steel trade might feel, somewhat hurt at the way in which Mr. Flower had put it that Bessemer steel would do instead of common puddled bars, and must take a very secondary position in the trade, he thought that Mr. Flower had a different meaning. Those who knew the tin-plate trade knew that it was divided pretty well into two categories. Stamping plates of the very highest quality were now almost universally made of Siemens-Martin bars, and the rest of the trade used Bessemer bars, or bars made from puddled iron in the ordinary way. A large portion of the tin plates made from Bessemer steel came very nearly up to the quality of the Siemens-Martin; but at the same time the Siemens-Martin tin plates had acquired a reputation, and had superseded charcoal plates. The merchants gave a higher price for plates guaranteed as Siemens-Martin steel than they would if they were made of Bessemer steel, however good the Bessemer steel might be; and while, as Mr. Riley had said, it was very essential that these historical records should be correct, and although Mr. Flower's paper might appear in its present form in the *Transactions*, yet the remarks that had been made would probably put the public right about it in the future. He thought Mr. Flower was substantially correct, in meaning that Bessemer steel did not come in to materially interfere with the tin-plate trade until two or three years ago.

Mr. P. C. **Gilchrist** said he should like to ask the author whether he found that steel plates required any longer or more careful annealing than the old charcoal iron plates, and also what proportion of manganese gave the best result. He thought the old charcoal iron process was perhaps the most interesting of any in metallurgy, and could not have been more carefully devised even by any one who had the most precise scientific knowledge; and when parting with it, it was interesting to recollect that the charcoal bars were melted in drops, and the reason why the charcoal iron differed so much in being very red-short from ordinary puddled iron was due to that fact. It was as near being steel as possible, and its red-shortness was entirely due to its being melted down in drops.

Mr. **John Head** said that there was one remark made by Mr. Riley which he could not allow to be passed unnoticed, and he regretted to have to say the remark referred to was not characterised by that degree of accuracy which the members were entitled to expect. In 1875 or 1877, the time which Mr. Flower referred to as that of the introduction of steel bars for tin plates at Landore, Dr. Siemens was not only a director, but also the consulting engineer, and virtually the director-general of the concern; and he (Mr. John Head) wished to ask Mr. Riley how long the works would have been carried on had Dr. Siemens not supported the company with funds. He must also say that besides Mr. Riley there was at Landore at the time referred to a very intelligent man, a chemist——

The **President** said he was afraid that Mr. Head was getting rather personal.

Mr. **John Head** said he could not allow the names of persons now in their graves to be passed over and advantage to be taken of the merit due to them. Mr. Arthur Willis was then chemist at Landore, and materially assisted in the carrying on of the works, and particularly in the extension of steel to fresh uses. Mr. Willis was well qualified to direct such operations, as he was engaged by Dr. Siemens when he made his experiments in manufacturing steel at Birmingham in 1868, and had thus acquired knowledge and experience in the manufacture of that metal for various purposes long before the Landore Works were thought of, and many years before Mr. Riley undertook the management of those works. Mr. Willis, moreover, was constantly in communication with Dr. Siemens regarding the technical part of the manufacture of steel, and specially when he was engaged in its development for new uses. Dr. Siemens urgently impressed upon his co-directors the necessity of finding new outlets for their product, and it was in consequence of those representations, and under his directions, that tin-plate bars were first produced at the Landore Works.

The PRESIDENT said, if no other gentleman was willing to address the meeting on this particular question, he would now do himself the pleasure of calling on Mr. Flower to make any remarks he might conceive to be necessary.

Mr. P. W. FLOWER, in reply, said that unfortunately his trade had no history, and if he had made a slight mistake in the date that he attributed to the adoption of Sir Henry Bessemer's metal, he was sorry for it. He had spoken of the first experiment that had ever come under his notice. It was at a neighbouring works at Aberdulais, but they could do nothing with it. Sir Henry had spoken of experiments which were made in London, and followed up at Llanelly, but the Dafen Company were obliged to abandon the process. Sir Henry's process had never been taken up by anybody else in the tin-plate trade, and he thought he was right in saying that those who required the highest class of steel had followed up the Siemens system in preference to the Bessemer. Sir Henry had been kind enough to interest and amuse them with some interesting specimens, but they were of no practical value. They must look to the trades, such as the petroleum trade, that he had spoken of. Consumers who cut up 1000 boxes daily certainly knew something about the quality of the material they dealt with. The quality of Siemens tin plates was now well known, and the whole world acknowledged it to be the best stuff they could get. As a consequence, the price was higher for that material, and as a further consequence, packers endeavoured to make use of a cheap substitute, and took up Bessemer tin plates in order to cheapen their packages. This experiment had broken down, and was so unsuccessful that large claims had been made in consequence. He, therefore, certainly considered that he was supported in saying that the world preferred Siemens to Bessemer steel. Sir Henry lived in a world of theory, but manufacturers lived in a world of trade, and had to consider the wants and requirements of the people who used their material. He did not think that he could suitably deal with the scientific points, because they were not in his way. He thought he had stated enough when he said that Siemens tin plates commanded higher prices, and that nobody in the trade who required good quality had put up a Bessemer converter. If it were necessary he could find any number of dealers who would come forward and state that when they wanted best work they ordered Siemens material. He had expected several gentlemen to be present, and with the permission of the meeting he would read a letter from Mr. Tregoning, who was as well known as anybody in England for the high quality of his plates. Mr. Jeans had been good enough to ask Mr. Tregoning to attend. After apologising for not being able to accept Mr. Jeans's invitation, he wrote—"I quite agree with Mr. Flower that for best tin plates, such as are made by his firm and mine, nothing can compete with the Siemens open-hearth process. We must not only have steel made by that process, but it must be made with the greatest care. I believe for such quality as I produce, steel made by the Bessemer process is altogether unreliable." That was the point; it all turned upon the word "reliable." It was not sufficient that a bar here and there should be good enough, but they had to produce them every day, and every week, and all the year round, in order to make a merchantable commodity. The Bessemer bar possessed a capriciousness that nobody seemed to be able to check. He hoped he should not be thought personal, but a chemist at one of the large ironworks was recently called to question for the quality of his tin bars; he said, "It is not my fault, those ingots vary within themselves; I can get one analysis from the top, and another from the bottom of the ingot."

The meeting was here adjourned until the following day.

THURSDAY, MAY 13TH.

THE proceedings of the Institute were resumed this morning—Sir HENRY BESSEMER, F.R.S., in the chair, followed (after the reading of his paper) by the President.

The CHAIRMAN said that Dr. Percy had received a very interesting letter from their friend Mr. Edward Williams, and it was proposed that the Secretary should read it to the meeting.

The SECRETARY then read the following letter:—

"CLEVELAND LODGE, MIDDLESBRO,
May 10, 1886.

"MY DEAR DR. PERCY,—Except once, when there was a railway accident, I have hitherto been at all of the general meetings of our Institute, and it is with the greatest regret that I am unable to join you to-day.

"If it were at all possible for me to come I would not stay away, if it were only to try to express, in something like adequate words, the gratitude I feel to the Council for awarding me the Bessemer Medal for the year; but my health is so exceedingly bad that I cannot leave home.

"I am very proud of the honour conferred upon me, and I venture to ask that you will be kind enough to express, as is fitting, my most grateful thanks.

"My son will be at the meeting, and glad to receive the medal on my behalf.

"I am afraid that my connection with the active work of iron and steel is at an end, and there is nothing left for me but to hope with all my heart that the Institute, and all those who are connected with it, may in the future prosper abundantly.—Yours very sincerely,

"EDWARD WILLIAMS.

"DR. PERCY, F.R.S., &c.,
President, Iron and Steel Institute."

The following paper was then read:—

ON STEEL WIRE OF HIGH TENACITY.

By the PRESIDENT.

In the address which I had the honour of delivering to the Iron and Steel Institute in May 1885, I mentioned steel wire of high tenacity, or, in other words, of great tensile strength, amounting to not less than 120 tons per square inch of transverse sectional area; and I also said that I had recently seen it stated that mild steel, in the form of rod or bar, had been produced of equal tensile strength. But, as no authoritative evidence was given of the truth of that statement, I determined to search for trustworthy information on the subject, and I have now the pleasure of communicating to the Institute the results which I have obtained.

In October last year I had, in concert with my friend, Colonel Markham, R.A., Director of Artillery Studies at Woolwich, and the members of the advanced class of artillery officers, the satisfaction of visiting the highly interesting and extensive steam-plough works of John Fowler & Co., at Leeds, a privilege which I gratefully acknowledge. My attention was particularly attracted to their steel wire ropes, for the excellence of which they have justly acquired a high and world-wide reputation. It then occurred to me to inquire concerning the tensile strength of the wire which was used for the purpose, when I was informed, to my astonishment, that it amounted to 150 tons or more. This information was most willingly imparted to me by Mr. Greig, the managing director, and one of the partners of the firm, from whom I received every courtesy and to whom I feel deeply indebted. That gentleman having kindly presented me with a sample of such wire, I was induced to ask my friend, Colonel Maitland, R.A., Superintendent of the Gun Factories at the Arsenal, to ascertain its tensile strength, and my friend, Sir Frederick Abel, Chemist to the War Department, to ascertain its chemical composition, as I have now no laboratory at my disposal. I need hardly say that my request was not in vain, and that both gentlemen unhesitatingly, and with the utmost goodwill, acceded to it, notwithstanding the time and labour necessarily involved in its fulfilment. I should not, however, have thus ventured to trespass on their kindness if I had not imagined that the results of their labours might prove useful to the public service.

Report of Colonel Maitland.

I present this valuable report just as I received it, as it would be impossible for me to suggest any improvement in the method of arrangement or in other respects. The kind of steel wire operated upon is that known as "Fowler's Special." It is hard and extraordinarily tough, and so rigid that, even with the aid of pliers, it requires the exercise of considerable manual force to bend it. It breaks when bent on itself, and the fractured surface is ragged, without showing any appearance of grain.

The following observations on the specific gravity of the wire have been made by Sir Frederick Abel's assistant, Mr. Deering, and communicated to me by the former, who, with his well-known sense of justice, has permitted me to state that the chemical composition of the wire has also been determined by the same gentleman, to whom, therefore, it gives me sincere pleasure to tender my thanks.

The specific gravity of the wire at 60° Fah., in its original state, that is, before Colonel Maitland began to operate upon it, was 7·8142, and after rupture 7·8082. The same weight of wire was used in both of these determinations; but, as it amounted only to about eight grammes, Mr. Deering suggests that the difference between the two specific gravities may not be greater than the probable error of experiment. It is, however, a difference in the direction which might have been anticipated. The specific gravity of the wire was increased by annealing from 7·8082 to 7·8402, a difference also in the direction to be expected, though Mr. Deering again suggests that it may be within the limits of possible error.

The process of annealing adopted was as follows. The wire was in three pieces, each from 3 to 3½ inches long, which together weighed about eight grammes, and were the same pieces as had served previously in the determination of the specific gravity after rupture or final straining in Colonel Maitland's experiments. They were packed round with asbestos (to check chilling), and pushed into a combustion tube about 8 inches long. At each end of the tube a plug of copper gauze, about 1½ inch long was inserted, the pieces of steel wire and asbestos lying between those two plugs. One end of the tube was sealed, and the other drawn out fine. The tube having been thus arranged, and placed in a gas combustion furnace, the plugs of copper gauze were first heated to redness with a view of absorbing the oxygen in the tube; afterwards the pieces of wire and asbestos were heated to very full redness and kept at that temperature for half an hour. The gas was gradually lowered and then extinguished, after which the top of the furnace (the bottom and sides of which were of clay) was covered with a tin-plate screen and left until the following day, when the wires were withdrawn: they were slightly dulled on the outside, but quite superficially.

No. I.

TESTS OF ROUND STEEL WIRE SENT BY COLONEL MARKHAM, R.A.

Diameter, 0·093 *inch* – 15·21 *lbs. per ton.*

Specimen, 50 *inches long.*

Tons per Square Inch.	Weight Applied.			Elongation in Inches.		Tons per Square Inch.	Weight Applied.			Elongation in Inches.	
	Cwts.	Qrs.	Lbs.	With Load.	Without Load.		Cwts.	Qrs.	Lbs.	With Load.	Without Load.
40	5	1	20	·125	...	98	13	1	5	·39	·067
41	5	2	7	·127	...	99	13	1	20	·4	·067
42	5	2	22	·13	...	100	13	2	8	·405	·079
43	5	3	9	·13	...	101	13	2	23	·41	·079
44	5	3	24	·135	...	102	13	3	10	·415	·079
45	6	0	11	·14	...	103	13	3	25	·42	·079
46	6	0	26	·144	...	104	14	0	12	·425	·079
47	6	1	13	·147	...	105	14	1	0	·43	·085
48	6	2	0	·15	...	106	14	1	15	·435	·085
49	6	2	15	·16	...	107	14	2	2	·44	·095
50	6	3	2	·17	...	108	14	2	17	·445	·095
51	6	3	19	·17	...	109	14	3	4	·45	·095
52	7	0	6	·175	...	110	14	3	20	·455	·097
53	7	0	21	·18	...	111	15	0	7	·46	·107
54	7	1	8	·185	·030	112	15	0	22	·48	·107
55	7	1	24	·185	·030	113	15	1	9	·49	·107
56	7	2	11	·19	·030	114	15	1	24	·49	·11
57	7	2	26	·19	·030	115	15	2	12	·5	·11
58	7	3	13	·2	·030	116	15	2	27	·51	·11
59	8	0	0	·205	·040	117	15	3	14	·52	·13
60	8	0	15	·21	·040	118	16	0	1	·53	·13
61	8	1	3	·215	·040	119	16	0	16	·54	·13
62	8	1	18	·22	·040	120	16	1	4	·55	·13
63	8	2	5	·225	·040	121	16	1	19	·56	·16
64	8	2	20	·23	·040	122	16	2	6	·57	·16
65	8	3	8	·235	·040	123	16	2	21	·58	·16
66	8	3	23	·24	·040	124	16	3	8	·59	·16
67	9	0	10	·245	·040	125	16	3	24	·6	·16
68	9	0	25	·245	·040	126	17	0	11	·62	·17
69	9	1	12	·245	·040	127	17	0	26	·63	·18
70	9	2	0	·25	·040	128	17	1	13	·64	·19
71	9	2	15	·25	·040	129	17	2	0	·65	·19
72	9	3	2	·255	·040	130	17	2	16	·66	·2
73	9	3	17	·26	·040	131	17	3	3	·665	·21
74	10	0	4	·265	·039	132	17	3	18	·67	·22
75	10	0	20	·27	·039	133	18	0	5	·68	·23
76	10	1	7	·27	·039	134	18	0	20	·7	·24
77	10	1	22	·275	·039	135	18	1	8	·71	·24
78	10	2	9	·275	·039	136	18	1	23	·73	·25
79	10	2	24	·28	·039	137	18	2	10	·75	·26
80	10	3	12	·28	·039	138	18	2	25	·76	·27
81	10	3	27	·29	·039	139	18	3	12	·78	·28
82	11	0	14	·29	·039	140	19	0	0	·79	·29
83	11	1	1	·3	·039	141	19	0	15	·81	·32
84	11	1	16	·305	·039	142	19	1	2	·84	·33
85	11	2	4	·31	·055	143	19	1	17	·87	·34
86	11	2	19	·315	·055	144	19	2	4	·89	·36
87	11	3	6	·32	·055	145	19	2	20	·92	·37
88	11	3	21	·325	·055	146	19	3	7	·94	·4
89	12	0	8	·33	·055	147	19	3	22	·98	·44
90	12	0	24	·34	·055	148	20	0	9	1·	·46
91	12	1	11	·34	·055	149	20	0	24	1·1	·48
92	12	1	26	·345	·055	150	20	1	12	1·2	·52
93	12	2	13	·35	·055	151	20	1	27	1·3	·61
94	12	3	0	·36	·057	152	20	2	14	1·35	·65
95	12	3	16	·365	·057	153	20	3	1	1·4	·75
96	13	0	3	·37	·057	154	20	3	16	Broke.	
97	13	0	18	·38	·067						

I have given Colonel Maitland's report *in extenso,* in order to show with what care and thoroughness the tensile strength of the wire has been determined. It broke under a load of 154 tons. The final elongation in the experiment immediately preceding rupture, was, *with* load 1·1 inch, and, *without* load, 0·75.

Another reason, which has induced me to communicate to the Institute the whole of the numerous observations recorded by Colonel Maitland in his report, is that I thought good use might be made of them by investigators who have shown special interest in studying the physical properties of metals, particularly of iron and steel, of whom I am happy to be able to say there are not a few at the present time. As examples I may be permitted to mention the names of Sir William Thomson and Mr. Hughes, to whom we are indebted for most interesting and important results in this line of research.

Composition of the Wire.

A portion of the wire on which Colonel Maitland had operated was selected for chemical analysis.

	Per Cent.
Carbon (total)	0·828
Manganese	0·587
Silicon	0·143
Sulphur	0·009
Copper	0·030
Phosphorus	nil

The wire was very carefully examined for chromium, titanium, and tungsten, but no trace of those metals was detected. Nearly the whole of the carbon, it may reasonably be inferred from the hardness of the wire, must have existed in the combined state. The percentage of carbon, it will be noticed, was greatly in excess of what is present in mild steel.

Being desirous of procuring thicker steel wire of the same kind as that operated upon in the foregoing experiments, I applied to Mr. Greig, who, with his characteristic kindness, forwarded to me three samples of such wire—0·132″, 0·159″, and 0·191″ in diameter, respectively. The tensile strength of each of these wires has been kindly determined by Colonel Maitland, whose reports on the subject *in extenso* are as follow:—

No. II.

Three Samples of Round Steel Wire, known as "Fowler's Special," of Larger Diameter than No. I.

Diameter of Wire = ·132″
Length of Piece Tested = ·100″

Strain applied in Tons per Square Inch of Section.	Extension with Load.	Permanent Extension without Load.	Strain applied in Tons per Square Inch of Section.	Extension with Load.	Permanent Extension without Load.
	Inches.	Inches.		Inches.	Inches.
20	·16	...	80	·74	0·057
30	·27	...	85	·81	0·1
40	·35	...	90	·92	0·17
50	·44	...	95	1·0	0·21
55	·5	...	100	1·1	0·26
60	·52	...	105	1·2	0·35
65	·55	...	110	1·3	0·41
70	·6	...	115	Broke	
75	·66	...			

No. III.

Diameter = ·159″

Tons.	Strain Applied.			Extension.		Tons.	Strain Applied.			Extension.	
	Cwts.	Qrs.	Lbs.	With Load.	Without Load.		Cwts.	Qrs.	Lbs.	With Load.	Without Load.
				Inches	Inches					Inches	Inches
10	3	3	25	·13	...	70	27	3	7	·83	·2
20	7	3	22	·22	...	75	29	3	5	·95	·27
30	11	3	19	·32	...	80	31	3	4	1·1	·35
40	15	3	16	·42	·039	85	33	3	2	1·2	·44
50	19	3	13	·53	·095	90	35	3	1	1·4	·61
55	21	3	11	·6	·1	95	37	2	26	1·8	·87
60	23	3	10	·66	·15	100	39	2	26	Bro	ke.
65	25	3	8	·75	·17						

No. IV.—*Diameter* = 191"

Tons.	Strain Applied.			Extension.		Tons.	Strain Applied.			Extension.	
	Cwts.	Qrs.	Lbs.	With Load.	Without Load.		Cwts.	Qrs.	Lbs.	With Load.	Without Load.
				Inches	Inches					Inches	Inches
10	5	2	26	·14	...	65	37	1	1	·7	·11
20	11	1	24	·23	...	70	40	0	14	·8	·15
30	17	0	22	·29	·039	75	42	3	27	·89	·22
40	22	3	20	·39	·095	80	45	3	12	1·1	·34
50	28	2	18	·49	·095	85	48	2	25	1·4	·52
55	31	3	3	·55	·1	90	51	2	10	Broke.	
60	34	1	16	·62	·1						

In order that Colonel Maitland's results may be readily compared with each other, I present them in the following tabulated form:—

No.	Diameter in Fractions of an Inch.	Tensile Strength in Tons of 2240 lbs.
1	0·093	154
2	0·132	115
3	0.159	100
4	0·191	90

Hence, it appears, that as the diameter increases, the tensile strength of the wire notably decreases. If the tensile strength of the metal, in Nos. 2, 3, 4, had been the same as in No. 1, it would be represented by the numbers 154, 309, 450, and 647, that is, calculating from the sectional areas of the wires respectively.

The steel pianoforte wire which I received from my friend, Dr. Pole, and to which I have previously alluded, was of considerably less diameter than the thinnest of "Fowler's Special," and yet its tensile strength was much inferior, as it did not exceed 120 tons. Of the four samples presented to me by Dr. Pole, three, measured by the Birmingham wire gauge, were 0·035", and the other 0·042" in diameter.

In December 1885 I was favoured with a letter from a gentleman referring to what I stated in my address last year concerning Dr. Pole's wire; and, as it contains valuable information on the subject, I have great satisfaction in communicating its contents to the Institute. My correspondent, whom I have the pleasure of personally knowing, and in whose veracity and ability to observe I have entire confidence, has given me full permission to publish those contents, but has requested me not to mention his name. I had informed him by letter of the result of Colonel Maitland's examination of "Fowler's Special," and received from him the following reply:—

"My best thanks for your kind letter of the 5th inst. (November 1885), in which, however, you omitted to give the diameter of the wire, which had a breaking strain of 154 tons per square inch. This breaking strain is certainly high; but if, as I expect, it was obtained in a wire of small diameter, say under ·060", it is not at all extraordinary. I have often come across wire with a still higher breaking strain; and as a proof I send you enclosed some tests of wire, of which I am enabled also to enclose samples, so that you can convince yourself of the correctness of my results.

"The one coil contains six tinned steel wires, which were obtained in August last, and gave tests as per Table A. These wires have meanwhile been laid up into a rope, from which I had the inclosed pieces cut off a few days ago. I had at the same time three more pieces cut off from the same end of the rope, the tests of which are given in Tables B, C, and D. I then had pieces cut off from the other end of the rope, the tests of which are contained in Table E.

"From the original tests, as per Table A, and from the re-tests, as per Tables B, C, D, and E, you will observe that three of the wires show throughout, with only one exception, a breaking strain of over 160 tons per square inch, whereas the other three wires are throughout weaker.

"Of course, all the diameters are measured over the tin, but the layer of tin is so thin that it may well be neglected in the calculations.

"The other coil contains bright steel wire, the tests of which were taken in 1884, and which are given in Table F. I have only this enclosed piece left, and could not, therefore, have it re-tested. You will notice that the sample is slightly oxidised, and may be weakened."

The tables above referred to are presented *in extenso,* and just as they were communicated by the anonymous author, as it is conceived that persons who may be specially interested in this subject of high tenacity in steel wire, especially such as have been practically engaged in investigating it, prefer a detailed account of the observations made and recorded by other experimenters to a mere general summary of their results.

TESTS OF TINNED STEEL WIRE.

Length tested = 10 *inches.*

No. of Coil.	A 1.				A 2.				B.				C.				D.				E.				Remarks.
			Breaking Strain.				Breaking Strain.				Breaking Strain.				Breaking Strain.				Breaking Strain.				Breaking Strain.		
	Diameter in Inches.	Percentage of Elongation before Breaking.	Actual in lbs.	Calculated per square inch in Tons.	Diameter in Inches.	Percentage of Elongation before Breaking.	Actual in lbs.	Calculated per square inch in Tons.	Diameter in Inches.	Percentage of Elongation before Breaking.	Actual in lbs.	Calculated per square inch in Tons.	Diameter in Inches.	Percentage of Elongation before Breaking.	Actual in lbs.	Calculated per square inch in Tons.	Diameter in Inches.	Percentage of Elongation before Breaking.	Actual in lbs.	Calculated per square inch in Tons.	Diameter in Inches.	Percentage of Elongation before Breaking.	Actual in lbs.	Calculated per square inch in Tons.	
1	·0195	1·4	113	168·9	·019	1·0	114	179·5	·019	1·0	103	162·2	·0191	1·3	111	173·0	·0191	1·2	100	155·8	·0191	1·1	94	146·5	A 1, pieces from outside of coil. A 2, pieces from inside of coil. B, C, D, E, re-tests. B, C, D, all cut from same end. E from other end of coil.
2	·0195	1·0	101	151·0	·0195	1·0	102	152·5	·019	0·8	95	149·6	·0190	1·0	90	141·7	·0192	1·3	110	169·6	·0189	1·3	101	160·7	
3	·0195	1·0	101	151·0	·0185	1·2	97	161·1	·018	1·2	110	193·0	·0188	1·0	93	149·6	·0192	1·4	110	169·6	·0190	1·0	95	149·6	
4	·019	1·0	103	162·2	·020	1·2	113	160·6	·019	1·0	90	141·7	·0191	1·2	87	135·6	·0192	1·1	95	146·5	·0188	1·4	111	178·5	
5	·020	1·0	103	146·4	·0195	1·0	97	145·0	·019	1·0	103	162·2	·0190	1·4	105	165·3	·0190	1·0	107	168·5	·0189	1·3	104	165·5	
6	·020	1·2	104	147·8	·0195	1·2	102	152·5	·0185	1·0	100	166·1	·0186	1·3	104	170·9	·0193	1·0	93	141·9	This piece of wire was lost.				

TESTS OF BRIGHT STEEL WIRE.

Length tested = 10 *inches.*

F

No.	Diameter in Inches.	Percentage of Elongation before Breaking.	Breaking Strain.		Remarks.
			Actual in Lbs.	Calculated per Square Inch in Tons.	
1	·030	2·5	269	169·9	These pieces were all cut from the same coil of wire. The diameter in these hard wires varies very much.
2	·030	2·6	269	169·9	
3	·030	2·8	264	166·7	
4	·030	2·5	261	164·8	

Concluding Remarks.

The information which, thus far, I have been able to collect respecting steel of high tenacity is such as to incline us not to accept without hesitation the accuracy of the statement to which I referred when I had the honour of addressing the Iron and Steel Institute in my last address, namely, that "mild steel in the form of rod or bar has been produced of the same strength" as Dr. Pole's wire, which, it will be remembered, amounted to 120 tons; and yet this statement was made with confidence, and widely circulated.

The interesting question, Why is it that steel, only when in the form of comparatively fine wire, should be capable of acquiring such a high degree of tenacity? remains to be solved. Is it that during the process of wire-drawing a more intimate interlocking, so to speak, of its particles may occur, which increases its resistance to the tearing asunder of those particles? That such resistance is enormously augmented is certain, but if it were due to the cause which I have just ventured to suggest another difficulty arises; for how, it may be asked, can a more intimate interlocking of its particles be reconciled with the fact that its specific gravity, so far from being increased, as in that case might reasonably be anticipated, is actually decreased, or, what is equivalent, its volume is augmented.

DISCUSSION.

The **Chairman** said that no doubt some gentlemen would favour them with observations on the subject of wire of great tensile strength. It was a matter of great interest, and well worthy of the deep consideration of the meeting.

Colonel **Maitland** said that Dr. Percy had so fully stated in his paper all that was required that he had very little to say. The reason why Dr. Percy asked him to conduct the tests of the wire in question was, as perhaps they all knew, that wire guns were now being made for the Government, or rather guns where the central tube had wire wound round it to give it strength. With respect to the figures that Dr. Percy had given, there was one little mistake that he was sure Dr. Percy would prefer that he should mention at once. On page 9 the tensile strength of the wires 1, 2, 3, 4, was given in tons per square inch, and he rather thought the figures 154, 309, 450, and 647 had been taken as absolute strengths. However, that was a mere detail. For the purpose of winding wire on guns it was found that wire of a rectangular or oblong section was most convenient. It lay more closely together than round section wire, and there were certain advantages in the way of joining. It was much easier to join flat wire than round wire. The breaking strain of the wire used in the Royal Gun Factory was from 90 to 110 tons per square inch. It was a quarter of an inch in width by $\frac{1}{16}$th in thickness, and the specification was 90 to 110 tons, with a yielding point not under 60 tons per square inch. By scarfing the ends of this wire together with about 15 inches scarfing and about 30 fine rivets they got a breaking strain of about 80 tons per square inch. He could quite understand that if they were to have the wire drawn down still further it would possess a still higher tensile strength, as the experiments recorded by Dr. Percy had shown. He did not, however, know that it would be of very much advantage to them from a gunmaking point of view, and therefore they stopped at that. Sir William Armstrong had made many experiments, and preferred a somewhat milder wire; he took wire which had a breaking strain of about 60 tons to the square inch and a little more elongation. Of course that required more of it to give the same strength. The French had been using a round wire of about 120 tons per square inch, but their results hitherto had not been very satisfactory in large guns. They had only made one very large gun, and that unfortunately failed from a defect in the manner of putting the gun together. The failure had nothing to do with the wire at all. Mr. Longridge had given great attention to the calculations for the initial strains, and worked them all out completely with the aid of Mr. Brooks, and was, in fact, the originator of the system. (He regretted Mr. Longridge was not present to speak for himself.) In his book were given really all the particulars in the fullest manner as to the best way of laying on wire to resist certain strains.

Mr. **Bedson** (of R. Johnson & Nephew's, Manchester) said he felt personally indebted to Dr. Percy for the paper he had given them on high-strain wire. It was to him a subject of great interest, he having to prepare large quantities of wire carrying a very high breaking strain. He felt a little surprise that a paper of this kind had not previously been brought before the Institute, and therefore felt doubly pleased with what Dr. Percy had already done. The high strain of 154 tons which was mentioned in the paper was unfortunately not accompanied with a tortional test. A high strain was easily obtainable at the sacrifice of the tortional test, but the tortional test was the *sine quâ non* of good high-strain wire. He would like to ask Dr. Percy if he would kindly favour the meeting with the tortional test in 8 inches, and state if it had been tried by pulling up by hand to see how tough the material was, for he found on page 4 of Colonel Maitland's report that it broke when bent on itself. The point was, that this high-strain wire should pull up close and open out three or four times to show that really the life was not taken out of the material by overdrawing it. The chemical analysis given was exceedingly interesting. The wire-drawing was really the means of putting the strength into the wire. To get these very high strains great care was of course necessary in the selection of the material, but given the chemical analysis, and given the same material, and putting it into the hands of two different men, totally different results might be obtained; and even with competent men a wire which would give from 120 to 150 tons breaking strain to the square inch would in one case break up as perfectly brittle, and in the other case, with the same size of wire that Dr. Percy had given them, give as much as from thirty to forty tortional tests in 8 inches; that was to say, taking a piece of wire 8 inches long, secured in a vice at one end, and at the other end turning it round on its own axis, they would get from thirty to forty twists. Here was a casual test he had taken up. With wire giving from 120 to 125 tons breaking strain per square inch, he obtained as many as from thirty-eight to thirty-nine tests in 8 inches, and this was a wire which would pull up four times, pull up, open out, and pull up tight like tying it in a knot. Another interesting point in Dr. Percy's paper had reference to thicker sized wires. That 154 tons strains could be obtained in the thin sizes was proved by Dr. Percy's sample, but the thick wire was really uncalled for, and would be unmanageable at that strain; the men could not bend it; it would want mechanical means for bending. But it was as easily obtained as the thin wire, provided that the wire-drawer had suitable plant and arrangements for it. It was simply, almost throughout, a mechanical operation, and depended entirely on the strength of the machinery and tools for its preparation. If a large quantity of wire, say of No. 1, = ·3 inch. in diameter, were called for, it could be produced to give the same strain as the small sample, only the plant and tools would be very expensive indeed. At page 12 of the paper there was a table showing the tests given by some special wire of very fine diameter. In very fine sizes, as he had said before, the test of a high breaking strain of say 160 tons was easily obtainable; but the great point in all things was not to sacrifice the life of the stuff for the sake of the strain, but to keep the strain down low, say to 125 tons to the square inch, and at the same time to retain a high efficiency and toughness. As Dr. Percy had just said, he did not think he had at any time seen a wire made from mild steel that would meet all these requirements; therefore the steel to give these high strains must necessarily be a steel of high carbon, of say at least ·8.

Dr. **Percy** said he very much regretted that he was not able to answer the question of Mr. Bedson, but he saw a gentleman present who would perhaps be able to give them information on the subject. He referred to Mr. Greig, who had had largely to do with the application of this wire.

Mr. **David Greig** said he had very little to add to this paper, as his own knowledge did not go very much beyond it. He very materially differed from the views of the last speaker as to getting the large wire to stand the same strain as the small. The strains which had been given could be very materially increased, but not without getting brittleness. Wire that would stand over 200 tons strain could be obtained, but such wire when applied to practical use was found to be brittle, and must contain too much carbon. The wire of which samples had been obtained from him was of such a nature that it would go five or six times round a pipe-stalk without breaking, and would also bend three times over a sharp vice without breaking. Now to do this they could not go beyond the strains which they had got. They had had it experimented on largely to see the highest point of hardness to which they could go, and beyond this they could not go. They found, too, another thing, that even with this hardness, if the wire were applied in a coal pit where it was run over a large quantity of pulleys, it even then crystallised in its work and became brittle. On the land on which it was used for steam ploughing, of course there was none of this knocking and crystallising. He did not know that he could add more to this paper.

The **Chairman** said he did not know whether Sir Frederick Abel, who had kindly assisted in this analysis, would like to say anything upon the subject, but the meeting would no doubt be pleased to hear him if he desired to do so.

Sir **Frederick Abel**, C.B., F.R.S., said he wished it were within his power to add anything to the information and to the very interesting facts which had been brought before them by Dr. Percy. He had himself thought carefully over the matter, and was sorry that he was not able to offer any suggestions to account for these variations in tenacity resulting from the drawing of wire down to different diameters, of which such an interesting illustration had been given by Dr. Percy. It did not appear to him—he said it with very great deference—that they could look to the very slight difference in the specific gravity between the wire before and after testing as any indication that a change in the specific gravity had actually been produced by submission to tensile strain. The difference between the two results obtained in the specific gravity determinations with the very small pieces of wire was very slight indeed. Moreover, he called to mind a statement made not long ago by Mr. William Anderson of Erith, in the course of a lecture which he delivered at the Royal Institution, to the effect that he had found the specific gravities of metals not to be affected by their being submitted to tensile strain. He was sorry he had not Mr. Anderson's results before him, but he believed they indicated that we could hardly look to the slight difference in the specific gravity of the two specimens of wire as bearing upon the question whether possibly the interlacing or interlocking of the steel particles or molecules, to which Dr. Percy had referred as a possible result of submission to the fine drawing process, might account for the increase in the strength of the material when drawn down to a comparatively thin wire. He did not know whether it might not be possible that some slight variation in the condition in which the iron carbide was distributed through steel wire might not make some little difference in the strength or the tenacity of the material after it had been drawn to different thicknesses. A great deal had still to be learned with regard to the influence which the distribution of the carbon in the form of iron carbide through steel had upon the physical properties of the material; and he had no doubt that the experiments of Professor Hughes, in which he was persevering with so much success, might throw light in the future on the effect of the mechanical treatment of steel upon its tenacity and other physical properties.

Mr. J. E. **Stead** said he would like to ask how this high-tension steel was made. It would be interesting to know whether it was crucible steel, Bessemer steel, or open-hearth steel. Whichever it was it seemed to be of exceptionally pure quality as regards phosphorus. He might say that he had frequently been in the habit of testing high-class wires quite equal to this in strength, and he had never come across anything in which phosphorus was absent.

Mr. **GREIG** said he believed it came from Messrs. Firth of Sheffield.

Mr. **BAUERMAN** said that what had been known for some time, and was generally known, viz., that the smaller the diameter of a test-piece the greater was the resistance obtained, came out very strikingly in the case of the comparison of the four wires. In the smallest they had a full strength of 150 tons; in the largest, which was about twice that diameter, they only had 90 tons. There was apparently a loss of 60 per cent. of the tensile resistance of the material. He thought that that might be mainly structural. Of course there was one great advantage which all very thin tests would have: the more nearly they approximated to a line the less chance there would be of having to work with resolved strains; the pull was more likely to be axial; the strains would be less, and therefore they would break under a straight pull rather than with the same strain at the end. He thought it might be structural in this way, that when they had a very small cylinder of that sort with very rigid material of that kind, they might be dealing with a substance which was not homogeneous throughout its section. For instance, they might have a very hard skin with a very high resistance upon a softer centre. Now it was clear that the proportional effect of that would be very much greater on the thinner than on the larger wire, so that they might be in the condition of having a very hard tube with a soft centre in which proportional resistance of the outer skin would be very much greater in the smaller than in the larger one. He did not know whether it was so. Possibly it might be something of the sort from the extraordinary way in which it came down in the annealing.

Sir **HENRY BESSEMER**, F.R.S., said there appeared to be one point upon which they had no information at present, but which he thought was one that must affect the tensile strength of wires of different diameters. It was known that a certain amount of work was necessary in order to develop the full strength of the metal, but he was not sufficiently acquainted with the art of wire-drawing to be able to say whether small wires and comparatively large ones were started from the same sized hole in the drawing plate, for if they were there would be a vast deal more work put into the small wire than into the large one. If any one would answer the following question it would be important. Supposing a wire one-eighth of an inch in diameter had a certain tensile strength, and was originally drawn from a rod of half an inch diameter; now, if they wanted to make a wire of a quarter of an inch in diameter, and commenced drawing it from a half-inch rod, would they obtain anything like the same tensile strength as was obtained in the smaller wire? That was a point which appeared to him of importance, and which he was unable to elucidate from any practical knowledge he had of wire-drawing. He thought it would be of great interest if any gentleman present who was well acquainted with the ordinary system of wire-drawing could answer that question.

Mr. BEDSON asked to be allowed to speak again. Mr. Greig had differed from him, but he still maintained that a wire, whether half an inch or one-eighth inch, could be made equal to stand a strain of 120 tons per square inch, provided the wire-drawer had the mechanical means for doing it.

The PRESIDENT said he had read a letter containing observations of interest concerning this subject. The writer expressed his regret at not being able to be present. Perhaps they would like to hear the chief points of the letter read.

The GENERAL SECRETARY then read a letter received from a member of the Institute unable to be present. The letter was addressed to the President, and was as follows:—

"In the last paragraph of your paper you ask, 'Why is it that small wire is capable of acquiring a higher degree of tenacity than the thicker sizes?' I do not pretend to answer the question, but I venture to suggest for your consideration the fact, that in the process of wire-drawing the wire hardens, and in a sense becomes more consolidated after every annealing, and a steel wire will stand so much more drawing (without annealing) than iron. The practice for both economy of production and to increase the tenacity is to anneal as seldom as possible. Another reason; after every annealing the wire has to be cleaned with acid, which requires the greatest possible care with steel, as it affects it most injuriously, and the wire before it is drawn is subjected to a certain degree of heat to get out the acid. You will readily see that in thick wire this may affect the tenacity very much more than in small sizes, and so to a large extent account for the difference. I say to a large extent, because the small sizes are capable of being drawn more than the thicker sizes without this annealing and subsequent cleaning, and the surfaces become, consequently, more of the nature of case-hardened iron or steel. The effect of acids upon steel would form a series of very interesting experiments, and, I think, would lead to much useful information; and I have no doubt Mr. Houghton is up to all this. To illustrate the difference: In the old days when 'spring wire' was first used, it was found better to clean iron by scouring in what was called 'scouring-barrels,' as it was found that iron so treated gave better results than same quality cleaned with the acid process. In spring wire great strength and tenacity were required, and so acid was avoided altogether. In the rod you can scour, but when it passes into wire you must clean with acid, hence great liability to injury."

Mr. Greig said he thought that the question asked was a very simple one to answer. The wires were not all drawn from the same dimension of rod. Suppose the case in which the big wire was drawn from an increased size of rod, then it appeared to him that the pressure of the drawing would not be sufficient to condense a large mass so solidly as the small mass, and that the larger mass would only be pressed to that extent on the outside, whereas the small wire would be pressed right through; consequently it would be sufficient that the pull necessary to draw the wire through did not press the internal part of the big wire, and therefore they would not get that tenacity out of the large wire which they would get out of the small wire.

Dr. Percy, in reply, said he only pretended to have been the means of submitting a few facts for the consideration of the meeting, and he had great satisfaction in having done so, seeing how much interest the subject had excited, and what valuable information had been received from highly competent men. He really had nothing more to add, except to thank Colonel Maitland for pointing out an error which he would be only too happy to correct, and for having made which he respectfully apologised. He had nothing more to say. [The error pointed out by Colonel Maitland is on page 72. On consideration, I thought it desirable not to erase it.—J. P.]

ON CERTAIN ACCESSORY PRODUCTS OF BLAST FURNACES.

BY MR. T. BLAIR, WINGERWORTH IRONWORKS, DERBYSHIRE.

IN the early part of 1884, the writer came across a peculiar deposit of fibrous silica in the "bear" of one of the furnaces of the Wingerworth Iron Company, near Chesterfield, and on submitting a sample to the President, he deemed it worthy of mention. Dr. Percy mentions a similar substance at p. 508 of his work on "Iron and Steel," and gives an analysis. Two analyses of this substance made by the writer give results as follow:—

	a.	*b.*
Silica	99·10	99·10
Alumina	...	0·80
Lime, &c. . . .	trace	trace

The specific gravity was only 1·7204, but a remarkable occurrence interfered with this estimation. Although the sample had been kept in a drawer for more than twelve months,* it emitted a hissing sound when plunged into cold water, exactly as caustic lime does.

After being kept two years, the same hissing occurred, and, upon boiling, the gas could not be got rid of. On some occasions the gas evolved burnt with a blue flashing flame; on others it did not do so. The conclusion arrived at was that the gas was either carbonic oxide or nitrogen. Yet it is noteworthy that the substance, after two years' keeping, still behaved in this extraordinary manner.

Dr. Percy gives 2·59 as the specific gravity of a specimen he got from Olsberg. Sir H. Roscoe says that tridymite has a specific gravity of 2·3. It is curious to note that amorphous silica has a specific gravity of 2·2; but, on strongly heating, it is transformed into tridymite, and the specific gravity increases. When rock-crystal is finely powdered and heated, the specific gravity decreases from 2·6 to 2·3.

---

* A sample of Mansfield sand exhibited shows, in the writer's opinion, the transition from New Red Permian sandstone to the amianthus alluded to.

Silica obtained by the wet way, as quartz, calcedony, or amorphous silica, polarises light, whereas that obtained by fusion does not. This deposit has far more of the characteristics of a sublimate. It was found in botryoidal masses, the convex side downwards, between the iron of the "bear," and the remains of the brickwork of the furnace bottom.

It is possible that there has been some reaction between carbonic oxide and the silicon contained in the iron. An analysis of the "bear" did not, however, show any excess of silicon—2·0 per cent. only.

It is worth mentioning that the "kish" which exudes from very grey iron is quite as frequently graphitoidal silicon as it is usually supposed to be graphitic carbon.

The writer has made several experiments with a view to determine the composition of the scale frequently found in large quantities on the faces of the pigs, and usually observable when ores containing manganese in perceptible quantity are being smelted. The following are analyses of samples collected at various times:—

	a.	*b.*	*c.*	*d.*
Silica (chiefly as sand) .	60·11	73·00	41·20	66·50
Iron (chiefly as Fe_3O_4) .	19·96	5·80	26·16	5·71
Manganese (as Mn_3O_4) .	12·25	10·10	2·16	13·54
Calcium (as Ca) . .	1·23	trace	2·00	...
Magnesium . . .	0·50	do.	0·75	...
Sulphur	1·11	...	...	0·206
Phosphorus . . .	1·28	...	...	0·150

The percentage of silica is, of course, extremely variable, and dependent upon the quantity of sand thrown upon the molten iron.

Messrs. Firmstone & Robertson, of New Jersey, U.S.A., published a paper, which was copied last year in *Iron*, in which they gave analyses of a similar scale. One of their analyses gives as under :—

Sesquioxide of iron	38·41
Silica	45·69
Alumina	3·56
Oxide of manganese	4·97
Lime	1·61
Magnesia	0·66
Titanic acid	5·59
Phosphoric acid	0·06
Sulphuric acid	trace
Chromic acid	0·48
Moisture	0·24
	101·27

They also quote another analysis, giving 7·18 per cent. of manganese. When this scale occurs, the iron is hard and chills well. It is a remarkable fact, that when "diamond" iron, which is a true spiegel, is being made, the furnace works hot, and the slag and metal run very fluid; but no one seems as yet to have fairly traced the occurrence of this iron to the presence of manganese in the mixture.

It is worthy of note that the whole of the sulphur passes into the slag when manganiferous ores are used.

Many ores, Spanish notably, contain zinc blende. Dr. Percy detected this in many English ironstones. The fume naturally contains the bulk of the zinc oxide, and it is by no means unusual to collect as much as *ten* tons per fortnight, when using such material. This deposit occurs in various forms. When near the furnace throat, it sometimes occurs in a dense black crust, but more frequently in stalactitic forms; further on as a light dust, and sometimes as leathery white cakes, or "philosopher's wool." It sometimes also occurs as a black mass, smelling strongly of ammonia, and containing shots of metallic zinc.

As is well known, zinc, burning in an ordinary flame, gives no spectrum other than a continuous one, but other metals do give spectroscopic indications of their presence.

In 1873 the writer made a number of spectrum analyses of the flame issuing from the cinder outlet of a furnace in Staffordshire. The lines of sodium and lithium were unmistakeable, but the two red potassium lines were only visible at intervals, and the broad red band of potassium was not to be found. On closely watching the violet end, it was thought that the violet potassium line glimmered out occasionally, but its actual presence was so doubtful that it was impossible to measure its position with the vernier. Three green lines near *Na a*, agreed with several green lines given in the potassium spectrum by Deschanel, but not by any other authority to the writer's knowledge. By deflagrating a mixture of potassium chlorate and sulphur, lines exactly agreeing in measurement were easily obtained. The red line of lithium is always to be found at the forepart, but never at any other part of the furnace. Sodium is, as usual, everywhere prevalent.

Returning to the question of zinc oxide in furnace fumes, some years ago, a peculiar brown slag formed in the flame flue of a Cowper stove, and on analysis gave the following result:—

Oxide of zinc	18·66
Ferrous oxide	2·57
Alumina	10·03
Manganous oxide	6·97
Potash	17·80
Soda	9·80
Silica	34·10
	99·93

Mr. W. Galbraith of Glengarnock, who made the analysis, calculates the composition thus:—

Zn_2SiO_4	25·57
Fe_2SiO_4	3·78
Al_2SiO_5	15·80
$MnSiO_4$	9·97
K_2SiO_3	29·10
Na_2SiO_3	14·50
Free SiO_2	1·20
	99·92

The fume coming from the furnace the same day gave:—

Oxide of zinc	70·90
Potash	2·20
Soda	1·00

Just recently, it became necessary to examine the flue dust from a common iron furnace, smelting Northampton and Lincolnshire ores. A sample collected at the bottom of the downcomer contained about half coke dust and half magnetic oxide of iron, with a little zinc oxide. That at the far end of the tubing was light yellow in colour, and one sample contained 48 per cent. of zinc oxide, coke dust being entirely absent. The former was strongly attracted by the magnet. The latter was not.

It is worthy of note that there is little or no fume from furnaces using coal.

Copper is often found in iron ore as malachite. Its presence in iron is said to prevent welding. It is not unusual to see the characteristic green flame of copper at the forepart, and in Elba ore there are often found feathery deposits of carbonate of copper.

Lead, with its natural congeners, silver and gold, are to be found. There is on record an analysis by Johnson & Matthey, showing 2 to 3 ounces of gold per ton in a Cornish iron ore.

Uranium has been found in traces. Vanadium is reported to have existed to the extent of 4·92 per cent (as vanadic acid), by Mr. Fairley in the *Proceedings* of this Institute for 1871.

Chromium appears to have an injurious effect on the quality of the pig iron produced, and prevents the production of a graphitic pig by, in some manner, abstracting the carbon. A firm of American smelters, who derived their supply of iron ore from a constant source, some twelve years ago were much puzzled and annoyed to find a remarkable depreciation in the quality and appearance of their pig. Examination proved that a cross vein, or veins, of ore containing from one to two per cent. of chromic acid, intersected that portion of the bed of ore then being wrought, and notable quantities of chromium were found in the pig iron. An account of this was published in the *Chemical News* about 1872.

Traces of nickel, cobalt, antimony, tin, bismuth, arsenic, and tungsten are sometimes found in iron ores, or pig iron, but it is difficult to say whether they affect the iron for good or evil. As regards nickel, a certain firm many years ago purchased from a dealer a quantity of what purported to be tap-cinder, but which turned out to be silicate of nickel, from a nickel-smelting works. It had a most extraordinary effect on the furnace; the cinder and iron were as fluid as water, and no doubt the furnace would have suffered severely had the trial been prolonged. The iron made was positively worthless.

Titanium is a substance which is usually missed, or estimated as silica on analysis. It certainly exists in many, if not in most ores. The well-known cyano-nitride of titanium is found in furnaces where ores containing that metal were never suspected to have been used; and it is a fact worthy of note, that specimens of this substance are seldom, if ever, found under the modern larger furnaces. Titanic acid has a very powerful effect on the working of a furnace, even when constituting so little as one per cent. of the charge. It renders the slag refractory, appears to abstract carbon from the pig, and spoils the appearance of the fracture. Even this small proportion gives a very characteristic appearance in the fracture. The iron runs smooth and clean, without adhering to the sand, and there appears to be a silvery white network crossing and re-crossing in every direction. What the effect is upon the quality of the iron, whether for good or evil, is very problematical. Titanium is perhaps the most useless and obnoxious element in the list, whether to the miner, the smelter, the glass-maker, or the chemist.

Among other elements, barium occurs largely in ores mined in the South of England. The writer has found as much as 12 per cent. of barium sulphate in an ore from Somersetshire, and it exists to a large extent in the Carthagena manganiferous ore. This base causes a thick, curdly, infusible, and very refractory slag.

It would be interesting if these notes elicited similar reminiscences from others who have been privileged to study the old type of furnaces, in which most of such products are usually found.

The PRESIDENT said he was sure they were exceedingly indebted to Mr. Blair for this most interesting paper, abounding in points which were calculated, he thought, to excite attention and promote discussion. As he referred to it at some length yesterday, especially that part which alluded to silica, in which he took so much interest, it was not necessary for him again to trespass upon their time. Besides that, they had so much business to get through that he did not want to intrude his observations upon the meeting, and much preferred hearing the expression of a variety of opinions or statements of men who had a large experience in matters of this kind. He hoped they would be favoured with remarks upon Mr. Blair's paper. It had been suggested that they might possibly with advantage have the next paper on the programme read before the discussion on Mr. Blair's paper was commenced. It was a paper which had been drawn up by his friend Mr. Bauerman, and he thought that that would be the most expedient course to adopt. He would therefore call upon Mr. Bauerman to read his paper.

NOTE ON A RARE BLAST FURNACE SLAG OF THE COMPOSITION OF GEHLENITE.

By H. BAUERMAN, V.P.G.S.

This slag was received by the President from Mr. Henry Aitkin of the Almond Ironworks, Falkirk, N.B., on the 17th of October 1885, accompanied with a series of analyses of materials and notes of the circumstances of its production. From these notes, which are very voluminous, it appears that a block of the slag weighing 12 to 15 tons was cast from the No. 2 furnace on the 1st of July 1879, and was broken up on the 19th of the same month, being then still hot in the centre.

The furnace, measuring 50 feet in height, 15 feet in diameter at the boshes, and 6½ feet at the twyer level (these latter dimensions being those of a newly-lined furnace), was blown by seven 3½-inch twyers with blast at 2¼–2½ lbs. pressure, heated to 850°–900° Fahr. The make for a period of four weeks ending on the 9th of July 1879 was 919 tons No. I. and 25 tons No. III. pig iron, from a mixture of 37¾ cwts. of six different kinds of clayband and blackband stone, with 2½ cwts. of Sommorostro campanil ore per ton of pig, and 9½ cwts. of limestone flux. The fuel consumed was at the rate of 26¾ cwts. of raw coal and 12¾ cwts. of coke.

No analysis of the iron was made at the time, but its composition is nearly represented by that of metal made in December 1875, when the furnace was similarly burdened, which was as follows:—

Almond No. 1 *Pig Iron.*

	Per cent.
Iron	90·560
Carbon combined	1·000
„ graphitic	2·650
Manganese	1·297
Silicon	3·360
Phosphorus	1·006
Sulphur	0·095
Total	99·968

The slag is light grey, or nearly white and cavernous in texture, being made up of crystalline plates with angular cavities between them. The plates on their flat sides show aggregations of crystals of rectangular shapes. The general appearance is very similar to that slag from Oldbury in South Staffordshire described by the President * and crystallographically examined by the late Professor W. H. Miller, F.R.S. The composition, as determined by Mr. Edgar Jackson, F.C.S., is given below, together with that of the slag from Oldbury for comparison :—

	Almond.	O.	Oldbury.	O.
SiO_2	28·59	14·85	28·32	14·71
Al_2O_3	22·32	10·45	24·24	11·39
CaO	36·76	13·70	40·12	12·53
MgO	7·78		2·79	
FeO	0·37		0·27	
MnO	0·50		0·07	
K_2O	0·21		0·26	
Na_2O	0·40			
CaS	3·25		3·38	
			CaSo₄ 0·26	
	100·21		100·09	
Oxygen ratios, $SiO_2 : (R_2O_3+RO)$		1: 1·63		1 : 1·61
,, quotient, $SiO_2/(R_2O_3+RO)$		0·61		0·62

This, the most basic in constitution of all blast-furnace slags, is of comparatively rare occurrence. In the memoir on crystalline slags recently published by Vogt (*Jernkonterets Annaler*, 1885, p. 270), analyses of three other examples are given as follows :—

	Linthorpe, Middlesbrough.	Oxygen.	Holzhausen, Hessen.	Oxygen.	Clarence, Durham.	Oxygen.
SiO_2 . . .	35·10	18·72	32·22	17·18	31·40	16·75
Al_2O_3 . . .	27·35	12·75	27·81	13·00	22·32	10·40
CaO . . .	28·14	11·07	17·35	11·20	30·92	13·38
MgO . . .	7·04		5·57		10·02	
MnO . . .	0·24		2·67		0·96	
FeO . . .	0·75		...		0·03	
K_2O . . .	Under	...	3·05		1·17	
Na_2O . . .	Do.	...	11·30		0·12	
CaS . . .	Do.	...	...		3·85	...
Total .	98·62		99·97		100·79	
Oxygen quotient	...	0·79	...	0·71	...	0·70

---

* *Metallurgy of Iron and Steel*, p. 503.

The first and third of these analyses were made at the School of Mines, Stockholm, in 1879.

From a rough computation of the slag-making material, based upon the analyses supplied as representing the composition of the stock smelted during the fortnight under review, the average composition would seem to be as follows (apart from unreduced iron and sulphide of calcium):—

	SiO_2.		Al_2O_3.		MgO.		MnO.		CaO.		
	36·75		16·90		10·18		3·48		32·69		...
Less reduced .	2·00		...		...		0·55		...		...
	34·25		...		...		2·93		...		...
Oxygen .	18·21		7·83	+	4·07	+	0·66	+	9·32	=	21·93

This is considerably more silicious, and approximates to a 9–10th or unisilicate type, supposing some part of the alumina not to be in combination with silica. If the analyses represent the materials actually used, the make of this slag must be exceptional.

When a thin slice of the slag is examined under a low power by transmitted light, it is seen to be made up of crystalline plates lying at all sorts of angles, and meeting in such a way as does not suggest any regular crystalline arrangement. The most prominent appearance presented by plates cut perpendicularly to their thickness, is a series of ragged-edged prismatic shapes, which, when they are sufficiently clear to let light through, are seen to be of doubly refracting material, and extinguish parallel to their lengths, thus indicating some mineral with rectangular axes. The spaces between the long plates are filled with others lying more nearly in the plane of the slide, and these show rectangular sections of crystals that are optically uniaxial, and therefore correspond to the forms described for gehlenite. They have a marked difference from the crystals of mellilite or humboldtilite found in slags which are also tetragonal, but when clear show in thin section a strong cleavage parallel to the sides of the prism. Owing to the rough and vesicular character of the slag, it is difficult to obtain sections of these crystals over any large surface, as a considerable proportion strip out in grinding. The crystals are in no instance clear over the entire surface, those even of a small individual being filled with enclosures (crystallites) of various kinds. The largest of these, though not the most prominent, are crystals of spinel in well-formed octahedra, mostly simply, but occasionally twined in groups of two and three. The most abundant inclusions are very fine arborescent or bush-like aggregates, having no definite shape under a magnifying power of 250 diameters, and larger particles of apparently the same material, which are arranged in cruciform and stellar groups resembling those of spinel figured in Stelzner's paper on spinel crystallites in the *Freiberger Jahrbuch,* 1881. They resemble the bush-like groups attributed by Vogt * to sulphide of calcium. Where the cruciform groups are largest, a square area of the crystal is cleared from the smaller inclusions, which suggests that they may be due to a coalescing of the smaller particles.

Natural gehlenite crystals are much more uniform in structure, being nearly free from inclusions. Those found are chiefly magnetite crystals and cloudy bands due to partial change into china clay.

The spinel crystals form a notable part of the slag, and may be isolated by treating it with hydrochloric acid and removing the silica by hydrofluoric acid, when they remain as well-defined octahedra with very brilliant faces, some being colourless, and others pale blue and perfectly transparent.

This occurrence of spinel in blast-furnace slags appears to have been first determined in 1880 by Muirhead (*Iron,* vol. xvi. p. 292), who found that highly aluminous slags left a proportion of a very intractable residue, varying in different instances from 5 to 17½ per cent. of the whole weight. These when analysed prove to be spinel, with about one-third of the magnesia replaced by lime. Mr. Jackson tells me that the amount in this slag is about 5 per cent. Vogt (p. 270) has from 2, 3, and 6½ per cent. of spinel in slags from Linthorpe, Clarence, and Coltness respectively. Spinel also occurs in mellilite slags as enclosures in the clear crystals, but they are very much smaller and more numerous than those found in the present instance. I have found these in slags from the South Durham Ironworks, Darlington, and from Elswick Works, Newcastle. The latter were, I believe, produced from the Ridsdale ore. These crystals, though perfectly visible under a high magnifying power, are exceedingly minute, probably not exceeding $\frac{1}{1000}$ inch across, but they are well formed and apparently always single crystals, in which respect they differ from the zinc spinels of the zinc retorts, which show a considerable tendency to form linear aggregates like those of alum crystals. Vogt,* after discussing the analyses of slags containing spinel, suggests that in those that are aluminous, highly basic, and contain from 5 to 10 per cent. of magnesia, the amount of spinel is proportional to the basicity, and that some such relation as the following may be observed:—

---

* *Op. cit.*, p. 290.

In a 0·5 silicate about 50 per cent. of the Al_2O_3 may exist as spinel.
„ 0·6 „ „ 35 „ „ „
„ 0·7 „ „ 20 „ „ „
„ 0·8 „ „ 10 „ „ „
„ 0·9 „ „ 5 „ „ „
„ 1·0 „ „ alumina is entirely basic.

The slag from Almond Works does not conform exactly to these conditions, as it should contain 8½ per cent. of spinel instead of 5 per cent. The coincidence is, however, sufficiently near to render this generalisation of value, when it is considered how small a number of observations has been available for its foundation.

Note.—Since the reading of the above paper the author has been kindly favoured by Mr. H. Louis with a section of one of the slags originally described by Mr. Muirhead. This is highly crystalline, but no square prismatic crystals are recognisable; the principal component appears to be of rhombic form, while the whole mass is thickly studded with octahedral crystals of spinel. These are mostly of a pure sapphire blue. In other respects the appearances are similar to those described.

---

* *Op. cit.*, p. 303.

DISCUSSION.

The CHAIRMAN said they had all listened with great attention to the admirable remarks made by Mr. Bauerman, who had taken an immense amount of pains in the matter. He was personally deeply grateful to Mr. Bauerman, and also to Mr. Edgar Jackson, both of them his friends, for having taken so much trouble in working this subject out so earnestly. He was sure they would receive the thanks of the meeting for their active assistance in a scientific problem of so much interest, and which, as they must have seen by the remarks just made by Mr. Bauerman, although apparently a sterile scientific fact, might possibly lead to important and valuable applications. The observations of Mr. Bauerman referred to the function of alumina with regard to silicious pig and so on.

Mr. BAUERMAN said that the fibrous silica referred to by Mr. Blair had been examined microscopically by Mr. Dick, who was present, and would, no doubt, give the results of his examination. As far as he had seen, the silica appeared to be amorphous, its action on polarised light being very similar to that of an amorphous fibrous substance. As regards the slag from the Cowper stove, he had seen it in process of formation at the furnaces then under Mr. Blair's charge, and supposed it be due to the effect of alkalies in promoting the volatilisation of zinc and manganese in the blast-furnace gases. It was well known that hard manganese ore or psilomelane contained a notable amount of alkalies. This mineral was commonly present in manganiferous Spanish ores. Mr. Galbraith's analysis and apportionment of the different bases was an ingenious one, and probably true in the main, except as regards the iron, which a microscopic examination showed to be present as magnetic oxide. It was not very likely, therefore, that any free silica was present. The mass of the slag was very finely crystalline—so fine, indeed, as to defy the effect of a very high magnifying power to resolve it into recognisable substances. The bulk of it was made up of fine feathery aggregates, such as were usually considered to be rudimentary forms of olivine, and there were numerous groups of bright yellow spheralitic grains, which were strongly double refracting, but showed no defined crystalline form. Silicate of zinc, Zn_2SiO_4, was recognisable in some of the thinnest and best-defined patches.

Mr. Blair had noticed malachite as a source of copper in iron ores, but it more frequently occurred in copper pyrites or some other sulphide. Some years ago, he received a sample on Lake Superior of a magnetic ore containing a small vein of grey copper ore, Cn_2S, running through it, which had not been observed when the ore was sent to the smelting furnace, as the two minerals were much alike in colour, and the metal in consequence deteriorated considerably. In such cases, probably, the sulphur was more injurious than the copper. In addition to the examples mentioned by the author of iron blast furnaces producing lead, that of the Silesian blast-furnaces might be mentioned as being the most considerable. The brown iron ore of this district, resulting from the alteration of masses of sulphides included in dolomite, was very much mixed up with carbonates and sulphides both of lead and zinc; so that in smelting there was an enormous deposit of zinc fume at the throat, which had hitherto prevented the general use of firebrick stoves in the district, while the reduced lead filtered through the joints of the hearth-bricks into the cross drying-flues, where a sump was made, heated by a fire, in order that the liquid lead could be ladled out. In one year as much as 2600 tons of lead had been so obtained from six furnaces.

The action of volatile substances in promoting the volatilisation of ether not usually credited with that property was well seen in the French system of making high manganiferous metal, where sulphate of baryta was used in order to increase the basicity of the slag, while keeping it moderately fusible, and so to prevent excessive reduction of silicon. According to Mr. Purcel, the gases of such processes contain an appreciable quantity of baryta in their fume.

Mr. Dick said he was sorry that he could not give any definite information in reference to the fibrous silica in question. He examined it some months ago, and whatever he found out then he had forgotten since. Just before coming to the meeting he found a paper, which he gave to Mr. Bauerman, with a few notes that he had made upon it at the time. The substance consisted of fine fibres, running from the centre to the circumference. It extinguished light between crossed nichols along the length of the fibres, as most of these things did; but the action was so very slight that it could scarcely be seen to exist in thin sections. It was something like the effect of bundles of spun-glass, such as were used for making peacocks' tails—things that glassblowers made. It did not behave like quartz or calcedony, or like agate, as he expected, but much more feebly. It consisted of alternate rings, like an onion, of the thickness, so far as he had examined them, of about $\frac{1}{200}$ of an inch. There was an extraordinarily regular development of these rings, as though the silica had grown in some kind of way, and had been periodically arrested. There was no difference exceeding one-third in the thickness of the rings; they seemed to have grown under certain nearly regular conditions. There was another matter he might allude to. He saw that the author said that when the fibrous silica was put in water it gave out gas. The small piece examined by Mr. Dick was put in turpentine for another purpose, and not in water, and it gave off no gas there. It seemed to disappear almost entirely, being of nearly the same refractive index as turpentine.

Mr. Blair said if they put a piece in a little water they would find that there was a copious evolution of gas.

Mr. Dick said if it did not give gas in turpentine it might not be silica.*

The President said he should like to hear some suggestion as to the mode of formation of silicon. No doubt there were gentlemen present who might be prepared to make some suggestion upon that point.

Mr. Louis said he wished to make some remarks concerning Mr. Muirhead's slags, which were referred to by Mr. Bauerman in his paper. When he first read Mr. Muirhead's paper in 1880 he noticed that the author did not state that he had found that spinel, as such, existed in the slag. He accordingly put himself in communication with Mr. Muirhead, and asked him for a sample of the slag. Mr. Muirhead sent him some of the powdered slag, and a small specimen of the same. He was thus enabled to corroborate Mr. Muirhead's analytical results. He had the specimen that was sent to him sliced, and examined it under the microscope, and thus discovered it to contain crystals of spinel, but never published this result. That morning he had re-examined it, and asked Mr. Rudler, of the Museum of Practical Geology, to examine it with him. That gentleman agreed with him as to the presence of the spinel crystals, and, moreover, said that this slag was decidedly different from that described by Mr. Bauerman. The mineral that accompanied the spinel was certainly not gehlenite; it consisted of fibrous, prism-shaped, long interlacing crystals; but he had not determined to what system they belonged, and in their interstices small crystals of well-defined spinel occurred. He thought that this was the more worthy of mention because the paragenesis of gehlenite with spinel was so well known as a natural occurrence that it might be advisable to put on record that spinel occurred in slags with some other mineral besides gehlenite, although he had not determined the nature of that other mineral.

---

* Since making the above remarks Mr. Dick has been supplied with larger pieces of the substance and found gas evolved in turpentine as in water. The observation may be repeated by drying the silica, and again putting it in water. Some further observations by Mr Dick will be found in the Appendix, having been received too late to appear here.

Mr. Bauerman said, in regard to the statement of Mr. Louis, he had mentioned in his paper that he had found spinel also in slags of a less basic character—in fact, the first sample he ever saw was one from a section of humboldtilite, in which the crystals were exceedingly minute, but exceedingly well formed. As regards Mr. Louis's mineral, he should like to ask whether he had any further observations than those he had stated? Was the oblique character of the associated silicate determined by its direction of maximum extinction?

Mr. Louis said the spinel did not extinguish at all. It was tolerably homogeneous.

Sir Lowthian Bell said that this extrusion, as it were, of silica from pig-iron came under his own observation nearly forty years ago. Unfortunately he kept no samples, and he had to speak of the composition of it simply from recollection. The first occasion on which it came under his notice was at the Wylam Ironworks. At that time the pig iron, on cooling, became coated with a covering of silica, and he fancied he might be entirely wrong —that it was due to the iron parting with a portion of its silicon, as happened with carbon at the moment of cooling; *i.e.*, there was an extrusion of silicon, which, becoming oxidised, covered the surface of the pig iron with a coating of silica in the state of filaments, very much like what he had been shown that morning, except that it was quite soft, and could be peeled off with the nail. The other case happened at the Clarence Ironworks, where an analysis was made of the substance, and there it contained a considerable quantity of manganese.

Mr. A. H. ALLEN said that Mr. Blair had mentioned the specific gravity of the sample of silica which he found in the bear of the blast-furnace as being ·7204, and compared it with Dr. Percy's own estimates of 2·59, and so forth, for other samples of silica; he presumed, therefore, that Mr. Blair really referred to what might be called the "apparent specific gravity" of the sample, including the pores; and hence it was not quite fair to compare it with the other. If he had taken means to counteract the effect of the porosity by determining the specific gravity of the produced sample, or by other suitable means, he presumed he would have arrived at a different result. He only wanted to make it clear whether Mr. Blair had operated in this manner or not.

Mr. BLAIR said that the specific gravity stated referred to the porous substance, owing to the impossibility of making the estimation in any other way.

Mr. EDWARD RILEY said he wished to make one remark in reference to what Sir Lowthian Bell had said. He had found exactly the same thing in castings on the necks of rolls where the silica came out from the iron. He must say he thought Sir Lowthian Bell's explanation was a most feasible one, and quite sufficient to account for the formation of this silica. Taking into consideration the fact that silicon and carbon were analogous in their properties in many instances, he thought it was a fair inference to draw, when they got a highly siliconised iron, that under the influence of heat the silicon would, he was going to say, crystallise out in the same way that the carbon came out, as kisch. This explanation of the formation of the silicon had certainly not occurred to him, but he thought it was a very good one, and, indeed, he was almost certain that it was so.

The PRESIDENT said that Mr. Blair proposed to give an ocular demonstration of the effect of plunging a specimen of silica into water.

Mr. BLAIR, having put the specimen in a glass of water, said it would be observed that the water hissed, and that gas was given off freely. It appeared that there was a decomposition of some constituent which he was unable to detect. The hissing showed that some action was taking place. He had only a few remarks to make in reply. Mr. Bauerman said he had only found lead in one case. He himself did not so much refer to lead in iron ores as to lead in the blast furnace. He remembered some years ago that at some works in South Staffordshire they found a quantity of Dudley limestone containing galena. In those days they only worked the blast to lead-heat, and used sticks of lead for trying it. On several occasions they had run as much lead from the tapping-hole as would suffice to test the heat at the holes in the tuyeres, perhaps for years together; that he found also in other limestones, and he had found it in iron ores. He did not think it was at all so uncommon as Mr. Bauerman appeared to have thought. As to the silica, he himself thought that the explanation given by Sir Lowthian Bell was the most feasible of all. As he stated in the paper, the iron which was found in contact with the silica contained only two per cent. of silicon, whereas the class of iron which was made in the furnace was usually somewhat higher than that. The furnace was in a bad state, and it only lasted six months. The silicon would sometimes be over three per cent. That fact almost appeared to show that the iron had parted with some of its silicon in the bottom of the furnace, and had, he should imagine, got oxidised again into silica in that form.

ON BLOW-HOLES IN OPEN-HEARTH STEEL.

By JOHN HEAD, F.G.S., Principal Assistant to Mr. Frederick Siemens, C.E., London.

Although mild steel is gradually displacing the better qualities of iron in the construction of boilers, ships, and bridges, its behaviour in certain cases is somewhat puzzling, and has sometimes given rise to much anxiety, fractures having occurred which, up to the present time, have been classed as of a mysterious character. It is the object of this paper to point out one of the defects to which these mysterious fractures may be attributed, and, at the same time, to show how that defect may be avoided in the manufacture of steel.

It is fortunate for steel manufacturers that Mr. W. Parker, the Chief Engineer Surveyor of Lloyds', has not allowed himself to be frightened by the mysterious failures which have occurred in the employment of steel; but, on the contrary, has made searching inquiries in each case brought under his notice, and manufacturers are much indebted to him, and to Mr. J. T. Milton, and Mr. Stromeyer, also of Lloyds', for the valuable reports which they have drawn up, and the papers they have written on the subject, copies of some of which were kindly placed at the author's disposal before he undertook to write this paper.

Those reports and papers treat of various matters in connection with the employment of steel for the construction of ships, boilers, and engines, and they lay great stress on the danger of working steel at what is termed a blue heat, that is, a heat ranging between straw colour and blue. It would be needless for the author to insist furthur on that important point, which has been so ably dealt with at the meetings of different institutions, and quite recently at the Institution of Civil Engineers on the reading of a paper by Mr. Stromeyer on the subject.

It is quite another matter the author wishes to deal with in this paper, viz.:—the presence of blow-holes in open-hearth steel—by which the strength and reliability of that metal are affected—and the means to be adopted for avoiding them.

Blow-holes in steel are of two kinds—those due to the contraction of the metal in cooling, and those due to the presence of imprisoned gases in its mass.

With care and by the use of proper appliances in casting, the first kind of blow-holes may in a great measure be avoided; but, even when present in steel ingots, inasmuch as they form vacuous cavities, the author agrees with the generally accepted theory that they will close upon the steel being subjected to pressure under hammers, presses, or mills, provided that air does not reach them before the weld is complete.

But with regard to the second kind of blow-holes the case is different; they can only be altered in form, except in so far as they may be got rid of by being brought to the surface of the metal by compression while the ingots are being worked up into merchantable forms. Supposing an ingot of steel containing gaseous blow-holes to be placed under the hammer or mill, the effect of the work done will be to compress the blow-holes, except in so far as some of them may be brought to the surface and so be removed; but the others will remain in the finished article, forming points of weakness which will show themselves on testing for tensile strain, particularly when the strain is applied transversely to the direction in which the metal has been worked. In the removal of blow-holes—those of the first kind by welding, and those of the second kind by bringing them to the surface of the metal, in working it up into merchantable forms—is to be attributed the improvement in quality which steel is found to acquire by compression after the ingot has been withdrawn from the mould.

It will be understood that the blow-holes due to imprisoned gases in steel are in most cases extremely numerous although minute in size, and they are not uniformly distributed in the ingots. They are similar to the cavities in glass, technically known as "seedy boil," which may be seen in the sample bottles, &c., which have been placed on the table, marked as made before the year 1883. Later on reference will again have to be made to glass and its manufacture, as affording a ready means of explaining the manner in which blow-holes in steel are produced and may be prevented.

During pouring of steel the gases it contains rise to the top of the ingot or casting so long as it is in a sufficiently liquid condition for that purpose. Such upward movement is soon arrested, however, by the metal assuming a plastic condition, but at the top there will always be found a greater number of blow-holes than at the bottom, and these will be much larger, as there is little head of metal at that point for compressing them. These blow-holes cause the rising or boiling action which has necessitated stoppering moulds with sand and wedge plates; whereas the metal, shrinking on cooling, should, on the contrary, cause the top of the ingot to be depressed, or to take a cup shape.

To the presence of gaseous blow-holes in steel in greater or less number or size, is due the difference in tensile strain which test-pieces from the same charge, and frequently from the same plate or bar, withstand. Although this circumstance has not hitherto been remarked upon, it has been admitted and allowed for in practice, for the Admiralty, the Board of Trade, and Lloyd's rules all allow a margin of 4 tons, between 26 and 30 tons, in the tensile strain of boiler plates, per square inch of sectional area, while for ships' plates, Lloyd's rules also allow the same margin of 4 tons, between 28 and 32 tons, which represents a range varying to the extent of one-seventh on the minimum strength insisted upon. In his paper, read at the Institute of Naval Architects in March of last year, Mr. Parker said:—

"This range of about 4 tons in the tensile strength of a plate of homogeneous metal like mild steel is very unsatisfactory."

This is the only comment which appears to have been made on this interesting subject.

In explanation of some of the failures in steel which have hitherto been classed as mysterious—no attempts at explaining them having been made—the author would suggest the possibility that in certain cases the gaseous blow-holes in an ingot may have sorted or arranged themselves in a series, thus forming a line of weakness in the plate or bar which has failed along that line when subjected to a strain much below that which test-pieces from the same plate or bar would withstand. The failure of the boiler-plates described in Mr. Parker's paper previously referred to, read at the Institution of Naval Architects, might be thus explained;

and Mr. Cuthill's remarks during the discussion which followed, seem to confirm that conclusion, for he said:—

"Some of the tests since made of the plate corroborate the original, while others are considerably higher, averaging about two tons over it. No explanation can be given as to this, other than that the original was taken from the scrap edges, while the higher ones and better in extension have been taken from the plate."

Other failures in steel have occurred while the metal was being worked up into ships or boilers, which may also be explained by the existence of blow-holes, forming a line of weakness in the plates but not necessarily a straight line. When the plates were riveted at the ends of the line of blow-holes, the tensile strength would not be much affected; but when riveted at the sides, cross-ways, there would be a certain stress produced which would lead to breaking. These failures are apparently complicated by the circumstance that they occurred when the men were away from their work, either during the dinner hour or at night, but on consideration it will be seen that this circumstance will materially assist in arriving at an explanation, for the rivets, when put in, were in a heated condition, and heated the plate to some extent, thereby causing a certain amount of expansion, which was sufficient to allow for the stress; but, on the men ceasing work, cooling took place, stress was put upon the plate, and it snapped across in the line of blow-holes, but not necessarily through any rivet-holes.

Speaking of the fractures in the steel plates supplied for the boilers of the Imperial Russian yacht *Livadia*, in their report dated the 16th February 1881, Mr. W. Parker and Mr. J. T. Milton say:—

"It was also suggested that the brittleness might have been induced by the absorption of gases."

It is to be regretted that this failure was not inquired into from the point of view here indicated, as such an inquiry could not have failed to elicit valuable information.

At some works agitating the molten metal in the ladle before pouring into the moulds is practised for the removal of gases from Bessemer steel. To our Past President, Sir Henry Bessemer, is due the honour of having first suggested that means; and in the year 1881 Mr. W. Allen brought before the meeting of this Institute a mechanical agitator which he had used with advantage. In the discussion which followed the reading of Mr. Allen's paper, the late Sir William Siemens spoke of some trials which he had made for poling molten steel in the ladle, in order to remove the gases it contained; but he was evidently aware that all these means were mere expedients, designed to mitigate a defect in steel manufacture which could not at that time be removed, for he added a remark I shall quote at length later on as bearing pointedly on the subject under consideration. It may be added that at a works where the manufacture of both Bessemer and open-hearth steel is carried on, the latter in furnaces heated by radiation from flame, an agitator is used for Bessemer steel, but is not required for open-hearth steel, which lies quite still in the moulds without having recourse to that means.

It has been supposed that the gases forming blow-holes in steel are bubbles of carbonic oxide formed by the reaction of iron oxide on the carbon in the manganiferous iron, added to the molten steel before it is poured into the moulds. This explanation, however, is open to the objection that manganiferous iron, being specifically heavier than steel, sinks immediately to the bottom of the molten metal to which it is added, being only momentarily in contact with the slag on the surface; and further that, as already pointed out, we find gaseous blow-holes, or "seedy boil," in glass, in the manufacture of which the addition of manganiferous iron, or any material containing carbon, at the end of the operation is not practised. If the gaseous blow-holes found in open-hearth steel are bubbles of carbonic oxide, hydrogen, or air, these gases may have been obtained from those used for melting, and this conclusion is supported by the fact that blow-holes or seedy boil are found in glass and steel melted by contact of flame, and are absent when melting without contact of flame is adopted.

Figs. 1 and 2 represent, respectively, longitudinal and transverse sections of a plate-glass melting furnace heated by contact of flame—such furnaces as were constructed by Messrs. Sir W. and F. Siemens about the year 1862. It will be seen that in this furnace the flame enters the heating-chamber at the level of the siege, and plays around and on the top of the pots, so as to obtain as much contact as possible between the flame and the materials to be heated; after doing its work in the heating-chamber the flame leaves at the end opposite that at which it may happen to enter at the time.

In the manufacture of plate-glass in such furnaces, the pots are charged at intervals with the mixture called "batch," being filled in the first instance, and refilled each time the materials are melted into glass, and thus diminish considerably in bulk. When the last charge has been melted, the greatest heat possible is put on for about an hour in order to heat the furnace and its contents thoroughly, after which gas is entirely, or nearly entirely, cut off, and the furnace closed, for about four hours, to allow the metal to fine. The fining of metal in this manner is for the purpose of removing "seedy boil," or blow-holes, the gases forming them rising to the surface during this operation. The fining operation will be completed in about an hour, but as plate-glass is required in a plastic condition, flame is kept out of the furnace for some hours longer before the metal is ready to be cast. The pots themselves, and their contents, are removed for that purpose, if large plates are to be produced; or the metal is ladled out of them when it is only required to produce small articles, such as tiles, ships' lights, &c.

The manufacture of window-glass is carried on in the same manner as plate-glass, so far as regards charging, melting, and fining; but as this glass is worked hotter than plate glass, less time is allowed for cooling before blowing is commenced. Some plate-glass furnaces hold as many as 24 and 30 pots, called cisterns, each containing about 12 cwts. of metal, so that each found in the larger furnace will weigh about 18 tons. Window-glass furnaces hold from 8 to 10 pots, each containing about 3 tons of glass; in bottle-glass furnaces, the pots employed are of smaller capacity than those used for window-glass, each holding about 1½ tons.

In order to remove "seedy boil" from glass melted by contact of flame, recourse must be had to the method of fining described, that is, the metal must be kept under the influence of heat without contact of flame. The operation will be more or less complete according to the temperature maintained in the furnace after the flame has been cut off, and the time which can be allowed for the glass to settle. In the manufacture of common bottles, cheapness of production rather than good quality of glass, having, until recently, been the object aimed at, the glass made, as shown by the bottles exhibited, contained much "seedy boil." In order to reduce the cost of production, and at the same time improve the quality, Mr. Frederick Siemens some years since invented the continuous glass melting process, which is adopted by all the leading bottle-makers in England and on the Continent, and is now being largely introduced for making window-glass. Since the introduction of this process, bottle-glass furnaces have been enormously increased both in their holding and working capacity. Up to 1882 the largest furnace of this kind was one of those built in England, the tank measuring 42 feet long × 16 feet wide, and holding about 150 tons of metal; but in combination with his new method of heating by radiation, Mr. Siemens, at Dresden, has been able to augment considerably the capacity of these furnaces, and a photograph is placed before the meeting of a circular furnace at his works measuring about 40 feet diameter, and holding about 230 tons of glass in fusion.

Figs. 3 and 4 show respectively longitudinal and transverse sections of a tank glass furnace heated by contact of flame; these diagrams being taken from the drawings of a furnace similar to that just referred to as holding 150 tons of glass. It will be seen that the flame is made to strike on to the metal in fusion, with the result that the glass made contained some "seedy boil"; but the glass produced in this furnace being better than that made in the furnaces which it superseded, no notice was taken of the circumstance at that time. As bottle glass-blowers commence work each week on Monday morning at six o'clock, and leave off work about the same time on Saturday morning, that day is available for cleaning the flues, during which operation the glass in the tank is partly refined, as already explained, further fining occurring on Sunday when the furnace not receiving any addition of fresh batch, gas and air have to be partly cut off, to reduce the heat, and under these conditions the flame would not come into contact with the metal in the tank. Thus a certain amount of refining was always practised in making glass by the continuous melting process, and, when necessary, the tank could be treated as a huge pot, all the heat possible being applied for some time, after which, the furnace doors and openings being closed, the flame would be reduced for a few hours by shutting off nearly all the gas and air. On one occasion the author dealt with a large tank furnace in that manner, and, as was expected, the metal was found afterwards to be of excellent quality and free from "seedy boil," or blow-holes.

By the adoption of Mr. Siemens' new method of heating furnaces by radiation, the loss of time and fuel consequent on fining when pot furnaces are employed is avoided, and "seedy boil" has disappeared in glass made by his continuous melting process. The presence of "seedy boil" in glass is therefore attributable to the contact of flame with materials in fusion, and is avoided when glass is melted by radiation from flame. The same result is obtained when glass is melted in closed pots; this is another but rather expensive way of avoiding contact of flame with materials in fusion, which in glass-making can only be adopted for the best qualities of glass, table glass for instance. Samples of glass melted by radiant heat are exhibited, and will be found to be quite free from "seedy boil." For these samples I am indebted to Mr. Siemens's Dresden works; the Tees Bottle Co., Stockton; the South Wales Glass Co., Newport; and other firms; some of the bottles having been turned in manufacture, have a better skin than others not made in the same manner, but they are all equally good in quality.

A good form of furnace for melting glass continuously is illustrated in figs. 7 and 8, Plate XXV. of Vol. II., 1884, of this Journal. In this furnace the gas and air enter into combustion at a certain distance above the metal in the tank, and the roof and walls are so arranged that the flame does not touch them, but sweeps round the heating chamber, in horse-shoe form, to the exit on the same side of the chamber as the admission ports. For the manufacture of glass this form of furnace offers many advantages, as, while providing a long run for flame, thus promoting perfect combustion, it gives a large extent of surface at which the workmen may be placed for gathering and working. This same form of furnace has also been adopted with advantage for melting steel on the open-hearth, or long furnaces holding 40 to 50 tons of steel are used, in which case they are made fish-bellied in plan so as to allow space for lateral expansion, as well as a long run for the flame. In Mr. Siemens's furnaces at Dresden, before referred to, the run of flame from the inlet to the outlet ports is nearly 100 feet, and the greatest uniformity of heat is thereby secured, combined with economy in working.

It has been shown that seedy boil or gaseous blow-holes are invariably found in glass when made in furnaces in which contact of the flame with the materials in fusion occurs, and it has been shown also that these defects may be removed by fining, or may be altogether prevented by melting glass without contact of flame—that is, in closed pots, or by radiant heat. The same remarks hold good with regard to steel. What is wanted at the end of the operation is that the fused metal should lie quiescent for a certain length of time under the influence of intense surface heat without contact of flame. In glass-making, "seedy boil" may be obviated in two ways—either by fining, as has been explained, or by melting without contact of flame, but for making steel on the open-hearth the latter alternative is alone practicable, for the reason that it is required to be tapped as hot as possible, whereas glass is worked in a semi-plastic condition.

The desirability of maintaining steel in a quiescent state for some time before pouring was recognised by the late Sir William Siemens, who, after describing the trials he had made of poling steel in the ladle, before referred to, made the following prescient remarks:—

"He had observed that considerable benefit accrued to the steel if, after it had been poured into the ladle, it were allowed to remain there under the protecting covering of slag to prevent decrease of temperature. The objection to this mode of proceeding was that, at this portion of the process, time was valuable; but he felt sure that great practical benefit would accrue if the steel could be kept in a quiescent fluid state for a quarter of an hour before pouring."

Of course it would not do to leave steel for a quarter of an hour in the ladle; it would partly set, or become plastic if that were done; and Sir William Siemens referred to that circumstance when speaking of time being valuable at that part of the operation.

In 1881 all furnaces were heated by contact of flame, but his genius enabled Sir William Siemens to forecast the requirements of steel manufacture to render the operation perfect. Mr. Frederick Siemens had not then invented his new method of heating by radiation, and had Sir William Siemens been spared to us a few years longer he would have been pleased to find in the application of this invention the solution of the remaining difficulty in steel manufacture.

There is another point to which, before concluding, I wish to draw your attention, at least briefly, viz., the analogy which exists between glass and the slag covering steel in open-hearth furnaces. If the slag were deprived of most of its iron it would become clear glass, hence the method of fining applied to glass-making will also apply to the slag covering molten steel; and that slag being pervious to gases striking on it, the steel beneath will be injuriously affected. In the early days of the open-hearth steel manufacture, glass was proposed as a protective covering for steel to prevent flame from penetrating to the molten metal beneath, and the slag floating on steel is perhaps even now looked upon as affording such protection. The behaviour of glass, when melted by contact of flame, will not, however, as has been shown, sustain that opinion.

In bringing to bear upon the subject of steel-making the results of experience obtained in another manufacture, members will understand that the author is dealing with figures worthy of their attention, the quantities of glass treated in continuous glass-melting furnaces varying between 80 and 230 tons at a time, and so far as the dimensions of these furnaces are concerned, it need only be said that they much exceed anything as yet employed in steel-making. This will become evident when we consider that the Tank furnace described, which is one of many built in England, would hold 375 tons of steel, and the furnace described as built at Dresden—Mr. Siemens having several furnaces of the same size in operation—would hold 575 tons of steel, the densities of steel and glass being taken as 7·0 and 2·8 respectively.

There can be no doubt that by manufacturing open-hearth steel free from gaseous blow-holes, the metal produced will be much stronger and more reliable than that made by contact of flame, and the result will be a greater confidence in its use. The merit and utility of Mr. Siemens' new method of heating by radiation by which this may be effected, are enhanced by the consideration that the production of steel of superior quality by its means is attended with considerable saving in cost of construction, in wear and tear of furnaces, and in waste of metal, the yield of sound bars or plates from a given weight of ingots being considerably more than was attainable with steel melted by contact of flame.

DISCUSSION.

Mr. **Russel Aitken** apologised for saying a word or two at that meeting, for although he was a member of the Institution of Civil Engineers, he was not a member of the Iron and Steel Institute. He had, however, given considerable attention to this subject of gases in metals, and had for some time been connected with experiments with a view to the improvement of iron and steel. They had spent many thousands of pounds upon those experiments without obtaining any commercial result, excepting a little increase in knowledge. This knowledge had been worked in gradually by succeeding inventors. He had been very much struck with the difficulty in the manufacture of steel caused by the quantity of gases, and it occurred to him that the proper way in which that question should be dealt with was by mechanical means. No doubt, as the paper pointed out very clearly, if steel were dealt with in the same way as glass was dealt with in Mr. Siemens' furnace, and kept hot for a long time by radiant heat, the gas in the metal would to a large extent be got rid of, and a sounder ingot would be obtained; but that would entirely depend on steel being kept in a heat proportionally higher above its melting point, as glass was now kept. But could such a heat be got and maintained? No doubt, also, the character of steel was improved by being kept melted, in the same way as the character of glass was improved, but that method was very much more expensive than it would be if any practical method of freeing steel from gases by mechanical means could be adopted. Referring to a diagram which he exhibited,* Mr. Aitken said that it showed one of the modes by which he suggested that that object could be attained. He had only recently taken up this subject again, because he had always found, in connection with most manufactures, that a time came when the subject was ripe for discussion. Seven years ago he took out a patent, but he had done nothing with it since. He spoke to several of the steel manufacturers, but they did not seem to be ripe for it; but now he thought the time had come when the question might be discussed with advantage. On the diagram there was represented a ladle filled with molten metal. The vacuum chamber was lowered from the top, and the nozzle projected into the upper part of the metal. The vacuum was then applied. The diagram represented a 15-ton ladle, and 4 tons of the metal were lifted up into the vacuum chamber. When Sir Henry Bessemer made his experiments, he took some molten steel from the Bessemer converter and poured it into a crucible, and he put that under a vacuum. The result was that, when the vacuum was applied, the metal swelled and almost exploded, and there was only one-third of it left in the pot. Therefore, when the metal was drawn by the vacuum into the vacuum chamber, he would expect that a very large expansion of metal would take place before settling down, and so the steel could be thoroughly mixed. When one charge was done the air would be admitted. The metal would then fall back into the ladle. After steel had been in the vacuum chamber it lost a certain amount of the gases, and thereby the metal was rendered more dense; further, the gases in escaping must absorb a certain amount of heat. Therefore, the metal would be still more dense, so that if the upper part of the metal in the ladle were drawn up into the vacuum chamber, and the air again admitted, it would be found that the steel so treated, being heavier, would settle at the bottom of the ladle when returned to it, as shown by the darker line on the diagram. He would expect that the next charge taken would settle in the same way, and so, by successive charges, they would be able to free the whole of the steel in the ladle from the gases. But the question then came to be, What would be the effect of that? His own impression was that steel would be very much strengthened by the extraction of the gases—he meant mechanically strengthened; and not only that, but he thought that if the method which he had described was applied to the Bessemer process, the use of spiegeleisen might be done away with, and that when the metal had been blown out to one-half or one-quarter per cent. of carbon, it might, without being blown any further, be turned into the ladle and worked into the vacuum, and the gases having been got rid of in that way, be cast into ingots, thus saving time and the cost of spiegeleisen. It was not an experiment he himself had performed, and until now he had not publicly brought it before any one; but he thought the matter might now be considered with advantage. Experiments had been made with ice. A glass tube, filled with pounded snow and water, was frozen in a freezing mixture. The rod was loaded at the end, and gradually bent into a circle. The same was done with water, charged with air. Again the rod was bent, but a greater weight was required. Water free from air was then frozen into a rod, and a still greater weight was required to bend it. The first rod corresponded to wrought iron, the second rod to steel as now made, and the third and strongest was what steel would be if the gases were removed from it before casting.

---

* This diagram is reproduced in the present volume.

Mr. BENJAMIN WALKER said he was sorry that a man of extensive experience in steel, like Mr. Head, should have put before the Institute the words "puzzling" and "mysterious" in reference to steel. There was no such thing as mystery; there was no puzzle about it at all. When there was anything wrong with the steel, it was because it had been badly manufactured and badly treated. In order to get an example of steel that had failed Mr. Head had had to go back to 1881. Those who were accustomed to use both steel and iron knew that there were more "wasters" in iron than in steel; but if an iron plate had a hole in it, into which one could put a knife, it was sent back, and nothing more was said about it; whereas if the same thing occurred with steel there would be a tremendous row, and it would be said that there was some mystery as to the cause of the failure. There was no such thing as puzzle about it at all. If a steel plate was bad, it was bad because it had been badly manufactured; its badness was due to want of skill; and just as the workmen increased in skill, so would the number of waster plates decrease. There was no comparison between the quality of steel and iron, especially when worked hot. Shapes could be rolled and made in steel such as could not be made in iron at all. He frequently came across a case where a very heavy load was being lifted, or some extra strain being put on a machine, and when he had remarked, "Is not that rather dangerous?" the common workman would reply, "No, sir; we have a steel shaft and a steel plate." The workman would say that because he had learned by rule of thumb and practical experience that the steel was more reliable than the iron plate. He had very little to say as to the remarks which Mr. Head had made about the blow-holes, which he thought constituted a very inferior part of the difficulties with which the steelmaker had to deal; and as to the failure Mr. Head had referred to, Mr. Walker thought that it did not occur owing to the presence of blow-holes, but simply from want of work; it was not well made. He had paid particular attention to it, and went over to Cammell's at the time and examined the whole subject; and when one had gone into it, it was evident that there was no mystery whatever. It was clear that the occurrence came about because there had not been sufficient work put into the metal. It must have been really wretched material, but that was not the fault of steel, as such. The failure should be put down to the workmen, and simply to the skill or want of skill that had been used in its making. Mr. Head had also made another assault on the old Bessemer process. He had said that at some works they used an apparatus like Mr. Allen's (the one suggested by Sir Henry Bessemer) to stir the metal about and get rid of the air. But that was quite the exception. There were very few people who employed anything of the kind. As good steel as he had ever seen had been made in the Bessemer converter. In the year 1864, at Woolwich Arsenal, canisters for powder and boxes of various fantastic shapes were made out of Bessemer steel. At Mr. Ellis's works they were making what were called the compound armour-plates, which were having a very great success. The other day Mr. Walker went to see one of these very large plates cast. When he saw the metal he exclaimed, "Hallo! Bessemer?" "Yes," was the reply; "Bessemer steel is the best." "Not open-hearth?" he asked again. "No," was the reply; "Bessemer, certainly; it is much the best." He had heard Mr. Ellis say those plates were made of Bessemer steel, and some of his friends thought they were made of Siemens steel, because they were so very good. Of course Mr. Head might say, "I am expressing the public opinion." But though he might be expressing the public opinion when he said that steel was a mysterious metal, he was not expressing the opinion of the men who used it.

Mr. **Windsor Richards** said he had had a considerable experience during the last year in making soft steel plates, and a good deal of difficulty and trouble from two causes, the first being the blow-holes, and the second—and by far the greatest trouble—the irregular distribution of the carbon in the steel. At the Eston

Works they made large ingots, which weighed about 4 tons, and were 6 feet high, 36 inches wide, and 16 inches thick. Their chemists' analyses, checked carefully by Mr. Stead, showed that the carbon in these ingots varied from ·10 to ·15. Such an ingot as he had described would make several plates, and the great difficulty and trouble was, with such variable carbon, to keep within the limit of 4 tons required by Lloyd's and the Admiralty, and the difficulties were increased when the same ingot was rolled into variable thicknesses of plates. In order to overcome this very serious difficulty very many things had been tried. They had tried the mechanical agitator in several forms, as recommended by Sir Henry Bessemer, and the "poling" of the molten metal by stirring with a very long pole, as suggested by the late Sir William Siemens, the latter being altogether ineffectual. They had also allowed the metal to rest in the converters for half an hour before pouring into the ladle, but that was not sufficient. The ferro-manganese was thrown into the converter first, and it was thought that the mixing would be more intimate on the whole being poured together into the ladle, but it was not successful. It then occurred to him to try pouring from the first ladle into a second ladle, and teeming into ingots in a supplementary pit. This was done with marked success, somewhat in the manner adopted by Mr. Riley—though not for the same purpose—as witnessed by the members of the Institute on their visit last year to the works of the Steel Company of Scotland. The steel which was unquiet and restless, having spongy ends, after being re-poured, became quiet in the moulds, and the carbon almost regularly distributed; and he would suggest to any of the members experiencing the difficulties he had named to try the contrivance described, and they would find their troubles much lessened.

Mr. James Riley said he was very pleased that Mr. Richards had made that last statement. He himself was going to call attention to the fact that when steel was made in furnaces where there was contact of the flame with the material, the metal was not always of the character described by Mr. Head. Those who last autumn visited the works of the Steel Company of Scotland would no doubt remember that the ingots which were then cast before them were not stoppered—not at Newton, at all events; and any day they pleased they might see the same thing done with regularity and constancy. So dead was the metal, and so free from the gases which Mr. Head had dilated upon, that there was no necessity for the stoppering. That being so, he did not see that there was any necessity to found such a theory as to the mysterious failures and the mysterious qualities of steel as Mr. Head had again brought before them, on the fact of blow-holes being present in the steel. He did not believe for one moment that failure was due to such a cause. At the meeting of a kindred institution, a fortnight or three weeks ago, there was something like an apotheosis of steel. Had they been present at the meeting of the Institution of Naval Architects, and heard what was there said, they would have found that there seemed to be a general concensus of opinion that now, at last, it might be taken for granted that the metal was sufficiently understood, and that henceforth there was to be no serious anxiety, so long as steelmakers would properly look after its manufacture. It was astonishing, therefore, to come there now and listen to a paper which tried to raise again the bogey as to the unsatisfactory nature of steel, and, for a certain purpose, suggested the introduction of a machine to prevent it. But that he would not refer to. He might perhaps be allowed to mention a little circumstance which had been known to him for a long time, but which he had never before referred to, because there were certain gentlemen to whom he was rather afraid of communicating too much information; it had sometimes returned upon him rather unexpectedly. These so-called mysterious failures were not due to the causes suggested. Too often, indeed, they were due, as he thought Mr. Richards was going to explain in his remarks, to the irregularity of the composition of the ingot in different parts. Mr. Richards had referred to the difference between a percentage of ·10 and ·15 of carbon. It might perhaps astonish them to know that not infrequently there was a difference of nearly ½ per cent. of carbon in an ingot. To many gentlemen present it was well enough known how that arose; but it was a difficulty which had to be met and faced, whether known or unknown, by those who were engaged in the manipulation of steel; and so surely as that was ignored, so surely were steelmakers landed in difficulties sooner or later with the material they sent out of their works. With regard to the very heavy ingots which were sometimes made, he believed it was impossible to cast such large masses of steel so that they should be of a uniform composition throughout. This was a well-known fact, and had, indeed, been stated once before, some years ago, at one of the discussions at the Institute. But the same thing obtained in the comparatively smaller ingots with which they were all dealing every day. It was to get over that to a certain extent that he had adopted the practice of pouring from one ladle to another, as Mr. Richards had mentioned; and whenever he called upon his people to make steel with more regularity for a certain definite specific purpose—with more regularity, if possible, than was ordinarily the case—they might depend upon it that steel would be made where it could be dealt with by the two ladles, and that a greater uniformity and a better result would invariably be found where that process was adopted. This matter of the liquation of carbon and phosphorus, and other elements, was a very serious one. It was this knowledge which had heretofore led him to advise Mr. Parker, time after time, to keep down the size of boiler plates, and not to let them go to that extreme extent to which there was a tendency at the present time. That had been his reason. Some of them might understand why he could not explicitly put that matter forth. The knowledge had been kept back; but he knew it, and they had carefully guarded against it. This irregularity was, of course, always found in the upper portion of the ingot. Remove that upper portion of the ingot, and get rid of those inequalities, and the material would be very much better than was ordinarily the case.

Mr. W. **Parker** said he was very pleased to hear Mr. Riley's remarks. For a long time the officers of Lloyd's Register had had before them the subject of the failure of steel plates, and had been endeavouring to discover why they failed or cracked, but this was, he thought, the first time a steelmaker had spoken out frankly and given them the benefit of his knowledge and experience. They knew at Lloyd's that steelmakers should know a very great deal more about this matter than any one else, and had resorted to several expedients in order to try to "draw" the steelmakers, and get at their opinions. He was, therefore, very glad to hear what Mr. Riley had said that day. As his name was associated with that paper, he wished to say that it must not be inferred from the mention of his name in the paper that he agreed with the conclusions arrived at by Mr. Head as to the cause of fractures in steel plates. He would not attempt to deal with the theory as to whether making steel and making glass were analogous, but he would briefly refer to the practical investigations which he had made into the causes of a great number of the fractures in steel plates. He did not wish to trouble the meeting with a long history of those cases, because he had had the pleasure of entering somewhat fully into them a few weeks ago at a meeting of the Institution of Civil Engineers, and the results would be found in the *Transactions* of that body. He might, however, be allowed to say, that it had been his privilege to investigate almost every accident of a serious nature that had taken place in steel plates in connection with marine boiler-making since 1878, and it was satisfactory to know that, with perhaps one exception, the cause of failure in all those cases had been clearly traced to improper manipulation, and not to any inherent defect in the material itself. Mr. Head had referred to some failures that took place in 1881, but those, as he said the other night, had been thoroughly cleared up, and they had nothing whatever to do with blow-holes, even of the minutest size, existing in the material. The plates that gave way were supposed to be brittle, although, as a matter of fact, test pieces had shown them to be perfectly ductile before being worked; but pieces taken from the very parts that cracked—in fact, from the exact fractures—were found to have the usual amount of ductility, bending, and stretching, thus indicating that latent strains had been set up in the plate whilst being worked, which, when relieved by cracking or tearing, restored the material to its normal condition.

Again, take a plate that had been injured either by local heating, spearing, or punching, or by torturing it in some other way; if that plate were afterwards made red-hot and allowed to cool, the whole of its strength and its normal qualities would be restored. But if blow-holes in the material had caused the plate to crack, he failed to see how, by making it hot and allowing it to cool, the blow-holes could be taken away, and the material restored, as it undoubtedly had been restored in such cases, to the condition it was in before the fracture occurred. No one regretted more than he did the difficulty which Mr. Richards had experienced of late, but he was quite satisfied that those difficulties did not arise because there were blow-holes or seedy-boils in the material. It was his privilege, just recently, to make an investigation into the cause of the giving way of a plate which Mr. Richards had made, and that was the first opportunity he had had of publicly explaining the conclusions he arrived at as to why the plate cracked. The plate was part of a large marine boiler shell; the boiler was being tested to 180 lbs. water-pressure—which represented only twice the intended working pressure—when the plate suddenly gave way at a pressure of 110 lbs., or, roughly speaking, about one-sixth of its supposed strength. On taking the plate out of the boiler and testing it, he found that it had a tensile strength of from 28 to 30 tons, a stretch of 25 per cent. in a length of 8 inches, and it bent double cold without any signs of distress, clearly proving to his mind that there had been some strain set up in the plate whilst it was being worked into form. He followed up the matter further by having the plate—which, he might mention, was made by the Siemens-Martin process—analysed, with the result that the material was found to be both mechanically and chemically perfect. He had no hesitation in saying that, so far as he could judge, the plate, when it left Messrs. Bolckow, Vaughan, & Company's works, was as good a plate as could be made; but still it gave way in the manner described. Now, in looking round at a number of plates at the same works, and in other works which his duties required him to visit, he found that steelmakers were in the habit of delivering very long and very large plates. Some were over 20 feet long, by 4 feet or 5 feet wide, and the majority of them were rolled in their cold condition into the form of the boiler-shell. In a great number of those plates he noticed that, instead of their being perfectly straight and flat, the middle of the plate had hillocks or puckers in it, showing that that particular part was somewhat longer than the edges. In that condition the plates were put through vertical rolls, bent cold to the required curvature, and then came out perfectly flat, with all the buckles or puckers rolled out of them. And he would ask, where had the extra metal in the middle of the plate gone to? It had, it seemed to

, been crushed into the sides of the plate, thereby producing initial strains in the metal of such an intensity as might be sufficient to cause the plate to crack, even without any pressure. Such treatment, he thought, should be considered improper, and should be avoided. If plates of such dimensions could not be rolled perfectly flat and fair, then they should be made smaller, which would enable them to be treated in a proper manner. He wished it to be understood, however, that in his experience he had never, with but one exception, found plates fractured because there had been inherent defects in the material. In concluding his remarks, he would like to say that, although this Institute did not, perhaps, generally know it, the shipowning world knew well that the introduction of that material, steel, for marine boiler-making purposes had been the greatest boon that steamship owners had had for the last fifteen years. Steam pressures had been increased from 70 lbs. or 80 lbs. per square inch to 150 lbs. or 170 lbs. This advance in pressure had admitted of a great improvement being made in the marine engine, and given to the steamship owners a reduction of over 20 per cent. in coal. Without such a material, this great reduction in fuel could not have been attained with the present form of boiler. Within the last fifteen years, half a million of money had been spent in the mercantile marine of the country in trying to make a boiler capable of working at these pressures; but all attempts had signally failed. Steel came to the rescue, and had it been introduced for that purpose some fifteen years ago the steamship owners of Great Britain would have had this half-million of money in their pockets, besides the value of the coal saved. To his mind, the improvements that had been effected in the marine engine and boiler, entirely due to the introduction of steel, marked the greatest stride that had been made in marine engineering since the introduction of the compound engine. There had been, during its introduction, a few failures. They had endeavoured to grapple with them, and to get to the bottom of them. And to show how far this material had been appreciated, he might say that not one out of the hundreds of boilers that came before Lloyd's Register was made of iron, and from 1878, when he had the honour of reading his first paper on this subject before the Institute of Naval Architects, to the present time, he found that

160,000 tons of steel had been used for manufacturing marine boilers in the mercantile marine of this country.

Mr. B. MARTELL (of Lloyd's) said he had really nothing to add after the exhaustive remarks of his colleague Mr. Parker, who had fully dealt with the question of the quality of that material, in which they took so much interest. He certainly felt, however, with Mr. Riley, very considerable surprise that at the present time a gentleman intimately connected with the manufacture of steel should come before an Institute like that and speak again about the mysterious fractures that they used to hear of in former times. That subject, he thought with Mr. Riley, had now been eliminated altogether from the discussions on mild steel. There were not now the phenomena that they used to consider mysterious with regard to those fractures. But, as Mr. Parker had said, if those fractures were carefully investigated they could always find the cause why the material failed. At the meetings of the Institution referred to by Mr. Riley, there was a paper read by a gentleman who had built a great number of ships. That gentleman was a member of the firm of Messrs. Denny & Co., and he instanced the thousands of pieces of mild steel that they had used within the last few years in the construction of ships, while the failures could almost be counted on the fingers of one's hands. To go and talk about uncertainty when they could insure such regularity as that was surely a mistake. Mr. Denny's statement was entirely confirmed by Mr. Martell's experience with regard to steel. It was used now with the greatest of confidence, and they had no hesitation in saying that, where it withstood the tests, and where it was carefully manufactured, mild steel could be used with the greatest confidence, and it was a great surprise to himself and his colleagues when they heard that there were any fractures whatever. It gave him a very great deal of pleasure to say that all the experience which they had had went to show that those so-called failures could be accounted for in a reasonable and satisfactory manner. But even supposing that this wonderful coincidence of blow-holes forming themselves into certain lines could produce weakness, as had been suggested in the paper, and supposing the sectional area of that line to represent one-twentieth, that would show that nineteen-twentieths of the solid material of the plates ld stand an ordinary strain of 30 tons to the square inch. t one-twentieth would amount to a ton and a half. Could they account for the breaking of a plate of that kind merely by a difference between 28½ and 30. It seemed to be altogether out of place to endeavour to assign failures to any such cause. However, there was no necessity to assign any cause, because they did not meet with those so-called mysteries at the present time, and, therefore, there was no necessity for accounting for them. Under those circumstances, he could, with Mr. Parker, express his very great satisfaction indeed that such a magnificent material as soft steel had been introduced, and he only hoped the date might very soon arrive when that material would entirely supersede iron in the construction of ships for the mercantile marine of this country.

Mr. E. A. COWPER said he thought they had cause to congratulate themselves on the investigations that had been made with reference to failures of steel during the last few years, particularly since 1881, and he thought their thanks were due to Mr. Parker for the very energetic way in which he had followed up every failure. The discussions that had taken place in that room during the last two months, and at the Institution of Naval Architects, had gone a great way to clench those efforts and fix them as certain facts. With regard to blow-holes, they knew that they must be bad in steel. Sir Joseph Whitworth reduced them by compressing them. If they cut off the top end of an ingot, they were safer than before. He quite agreed with some of the speakers who advised that very long plates should not be used in marine boilers, because in a very long plate they had a greater chance of variation of quality. If they had one plate rather harder than another, or one part of one plate harder than another part, and a softer plate were placed alongside it, the strain must come upon the hardest or stiffest plate of the two. Those curves of Mr. Parker's showed the degree of elasticity and ductility of the plates, and the different degrees of hardness; they were shown conclusively. Whether it was in the boiler or in the ship, if the hard plate were alongside a soft plate, the hard plate would take the strain when the ship got on the rocks. With regard to the furnace spoken of in the paper, he had carefully gone into the subject, and had had several conversations with Mr. Frederick

Siemens about it, even as late as yesterday. He thought that the higher roof, by allowing the products of combustion to form a flame, clear of the roof as far as possible—whether they were working on glass or steel—was a most distinct improvement; it saved the furnace, it gave a higher temperature, it saved the fuel, and it gave a better product. There was no occasion for going into a number of theories about blow-holes, because if the metal was made hotter, and kept quiet, those bubbles would come out if they existed in the metal. Therefore the new furnace was better than the old one, because it would heat by radiation, give a higher temperature, and keep the flame, with its impurities, from the metal, as well as to a great extent from cutting the furnace.

Mr. D. GREIG said he should like just to say a few words upon this subject. He thought he had done a little in the manufacture of boilers from steel, and knew something about it. He had made two thousand boilers, and to him the discussions which took place on this subject were unaccountable. It really appeared to him that the intelligence of the nation was going down, when the time of such a meeting could be occupied with such a subject at all. It beat him; he could not understand it. His experience of steel was that it was twice as good as Low Moor iron under any circumstances, and if they wished information as to the cracks and flaws, the books of his firm were at their disposal to see the number of wasters from steel plates compared with iron. There was no talk about the wasters in iron plates that went away from Fowler's works before steel was introduced, and the number of wasters since steel was introduced was not one-tenth of that which they had had formerly. The cracking and honeycombing were due to the ignorance of the manufacturer as a general rule; they might in some cases be due to the material. He did not say that all the stuff they got was quite perfect. They had been talking of drilling all the holes. He believed in drilling holes for an altogether different reason from that given by other people, when they said that the stuff would not stand punching. To him that was simply nonsense. The stuff would stand it, but the better construction and more accurate workmanship of the boiler entailed drilling the plates before they were put together. He would prefer punching the plates for the sake of getting to know the material, because if he shut his eyes and was taken through a boiler shop, he could tell whether the material was right by hearing the punching going on. That was sufficient to indicate whether there was too much carbon, and whether the plate was too hard or not. He certainly hoped that people would begin to put their heads together, and try to know something about this material, which was invaluable. It was nonsense to talk about the other material.

Sir NATHANIEL BARNABY said he just wished to say a word on this subject. He did not think Mr. Head had quite done his subject justice, if he might be permitted to say so, in allowing it to appear that the question lay between steel plates and iron plates. He thought, as those gentlemen thought who had previously spoken, that that matter was thoroughly settled: to his mind it had been settled for a long time. It seemed to him that the importance of the paper rather pointed to the controversy between the steelmaker and the forgeman. The difficulties now did not at all lie in platemaking, for in that they had been got over, but in making sound steel castings to take the place of forgings. All those who were concerned in shipbuilding, and had to feel a very great interest in the change which was rapidly taking place in the use of castings instead of forgings, had found many difficulties arising from the want of soundness in casting. Mr. Riley knew something about that. He knew, for example, that a number of "racers," for gun-carriages to run upon, had been made, and that a very large portion of them turned out to be unsound. The other day he had had the advantage of seeing in Mr. Roach's workshop in New York a steel shaft which had been made for a ship of war there, called the *Dolphin*. It had been hammered down to half its size, and when they put it in the ship and tried it, it broke. The shaft showed large holes in the centre. Just in the centre of the shaft there were two fissures, of very considerable size, crossing each other; and it seemed to him, in reading Mr. Head's paper, that the important method he was describing was one which rather touched the making of those great castings to displace costly and untrustworthy forgings than anything else. If it should appear that there was any advantage in this new method by which greater soundness could be procured in the castings, then he thought steelmakers were not consulting their true interests if they contented themselves with saying that they had had very great success indeed, that they had made splendid steel-plates for ships and boilers—which was true—and if they therefore proposed to stop there. They ought not to content themselves until they could make thoroughly sound castings. When they did that, the day of the iron forgeman would be over—and the sooner the better.

Mr. E. W. **Harvey** wished to say a few words upon the two kinds of furnaces which Mr. Head had mentioned in his paper (and to which Mr. Cowper also had referred) for making open-hearth steel, namely, that older kind which Mr. Frederick Siemens called a "flame-contact" furnace, and secondly, the "radiation" furnace. During the last few years he had had opportunities of practically dealing with the making of steel from the two kinds of furnaces. At some works he had had them side by side, some furnaces working on the old principle, and some on the new; and in every case—for tin-plate metal, for boiler-plates, and for castings—the new radiation furnace of Mr. Frederick Siemens gave distinctly better results. In some cases he had taken the metal from such a furnace, at say ·11 of carbon (which was low, and usually had the greatest tendency to boil and froth), and cast it into ingots without any stoppering on the tops, and those ingots had remained—he would not say quite flat, but with very solid tops. Then he had taken similar metal (as regards carbon) from the other kind of furnace practically at the same heat, and apparently under the same conditions, and it had boiled up, and sometimes come over the top of the mould if it had not been stoppered in some way. From that, and many other trials, he must conclude that the new furnace had decided advantages over the old. In the first place, the gases did not play directly upon the metal, and were consequently not absorbed by it; in the second place, there seemed to be a more regular diffusion of the heat, which caused the metal to cast sounder in the ingot. In speaking about this furnace there appeared to be a doubt in many minds as to the capability of getting sufficient heat. It had been said that the new furnace had too high a roof, and they would not be able to attain sufficient heat in the metal. He must say that his experience was just the opposite. In a few cases there had not been sufficient heat, and there had been skulls in the ladle, but he had always found that that was due, either to the inferior workmanship in the construction of the furnace (where the old type had been altered to the new), or to unskilful working. The new radiation furnaces required a little different manipulation in points of detail from the old ones. As a proof that the heat could be obtained satisfactorily in the radiation furnaces, he might add that there had been produced regularly at steelworks he had been connected with, eleven, twelve, and thirteen charges of tin bar metal per week, with a carbon of from ·11 to ·14 per cent. In making steel castings also from such furnaces he had been able, in many instances, to go sixteen, eighteen, or twenty minutes during the casting operation and still had no skull in the ladle. Sometimes the casting operation had lasted twenty-three or twenty-four minutes with the same result. The time had been carefully counted by himself. He thought that spoke amply for the heat which could be obtained in those new furnaces. With reference to the suggestion that Sir William Siemens had made, namely, to keep the metal in the ladle some time before casting, he remembered trying this at the steelworks where he was then engaged—not for fifteen minutes, as Sir William Siemens suggested, because (as most steelmakers know) the metal would be too liable to set by the end of that time; but he allowed the metal, after running it into the ladle, to rest under a coating of slag for 1½ to 3 minutes before casting, and he found by repeated trials that the metal was considerably improved for cogging purposes. There were no cracks or visible ruptures on the sides of the ingots, such as were sometimes seen when metal was cast in the usual manner. There was something in that. Then he tried another experiment in the same direction. Instead of allowing the metal to run into the ladle, and keeping it there a few minutes before pouring, he turned off a certain amount of gas in the furnace for a few minutes before tapping, thus cooling the metal somewhat, and allowing the occluded gases free access to the top. This gave a similar result. They got the ingots to cog down into bars in a better way (free from "ropiness" or side ruptures), but this mode of working was ultimately abandoned because they could not get the men to gauge it to the required nicety. They would occasionally let metal stand too long before teeming, and so cause skulls in the ladles, or not long enough to make an appreciable difference in soundness of ingots. He would, therefore, say that if they could get this improved result without the risk mentioned (and his experience was that they could get more soundness in ingots) by having a furnace constructed differently —like that of Mr. Frederick Siemens—it behoved every steel manufacturer to look into the matter, and adopt that form of furnace which would give the greatest soundness compatible with keeping the furnace at the highest heat before tapping, and without allowing it to rest in the ladle or do anything tending to make the metal set. He would like to say a word about the absorption of sulphur which sometimes took place from the gases which were passing over the metal in an open-hearth furnace. There was not much literature upon this subject, and varying opinions existed; but he remembered some time ago making some experiments with steels varying from ·3 to ·6 of carbon. There was in most cases more sulphur (to the extent of ·01 to ·035) found in the ingot metal than he could calculate in the mixture after analyses had been conducted and an allowance made for a certain amount of waste by oxidation, which always took place in the open-hearth furnace. Those experiments showed that there was practically ·02 per cent. sulphur absorbed by the metal from gases passing over it. The furnace used was of the old-fashioned "dip-roof" kind, and the gases therefore played more or less in direct contact with the metal. In a recent report from Sweden, by Messrs. Odelstjerva & Forsberg, it was stated, as proved in Sweden, that sulphur was appreciably attracted to the metal, or absorbed by it, from the gases passing over the charge in an open-hearth furnace, and those gentlemen put the condition "when in direct contact with the flame." There was an absorption (proved from a considerable number of experiments) of ·015 to ·025 of sulphur, and sometimes as much as ·3 per cent. of sulphur, due to this cause entirely; and it was said that when 3 kilogrammes of lime in a crushed state were added to 43 kilogrammes of coal in the gas-producers, the absorption of sulphur could not be so traced— it was very much less or none at all. He mentioned this because, in a furnace such as Mr. Siemens's new form, where the gases did not come into direct contact with the metal, it was very probable that there would not be this absorption of sulphur which had been noticed in the old furnaces, that had the flame playing upon the metal.

The PRESIDENT said he saw his friend Mr. Ellis present, and would like to ask him a question. He thought that not long ago Mr. Ellis invented a method of keeping the top of the ingot mould highly heated for a long time after pouring in the molten metal, with a view to giving time for a more thorough elimination of the bubbles of gas. He would like to ask him if he had tested the merit of that invention.

Mr. J. D. ELLIS said he had made a great number of experiments for the purpose of endeavouring to keep the heat of the top of the mould so great that the metal should continue liquid as long as possible, so as to allow the gases to escape, and the metal to settle soundly. He found, by using a heated clay top, he could succeed to a great extent; but there were several difficulties connected with keeping the clay top sufficiently hot, and by using a different method, which they now applied to all their large ingots, they could obtain soundness at the top of the ingot in a more satisfactory manner. Therefore, after using the clay-top system for some time, they had discontinued doing so, having found the other system much more reliable.

Mr. J. HARDISTY said he had listened with great interest to the paper now under discussion, as it was one in regard to which he had had considerable experience. The first furnace built at the Elswick works was from Sir William Siemens's drawings. It had very high ports, and the centre of the roof was no less than 60 inches lower than the ends. Very great care was required in the management of that furnace, and it was hardly possible to get the flame on to the metal without first striking the roof, the result being that repairs were necessary after a very few charges. The ports were lowered 15 inches and the roof raised 10 inches at the centre, thus reducing the slope by 25 inches. This gave very much better results, and whenever repairs were required, the furnace was altered, to try and determine the best height of roof and inclination of ports, and also to receive 25-ton instead of 15-ton charges. The best effect was obtained with a straight roof, ports 15 inches lower than at first, and inclined at an angle of 30°, instead of being horizontal, as recommended by Mr. Siemens. The flame then impinged on the surface of the bath, at about the middle of the furnace. If, however, as they were asked to believe, the radiation furnace, with a high roof, was always the best, he should like Mr. Head to explain why they had often been able to melt 20-ton charges in the same and occasionally in slightly less time than a charge of 6 tons in the same furnace. In his opinion, a roof ought to be high enough to afford sufficient room for complete combustion of the gas in the melting-chamber, and for the flame to be fully developed, but anything beyond that was objectionable. He did not see the necessity for making any special arrangements in a melting furnace to get rid of the gases in the steel, for if proper attention was paid to the working of the charge, there was no need to have any gases in it at the end of the operation. The question depended upon the selection of the materials in the first place, and then on the manner in which they were worked and transferred to the moulds. The most important point in the melting was the rapidity with which the ore was fed. Iron smelted from Spanish ores usually contained about one per cent. of manganese; and if those or similar irons were used and the ore fed slowly, there was not the slightest difficulty in obtaining solid samples during the whole operation. With regard to casting, the best method was to let the metal run as slowly as possible out of the ladle into the mould, through a bottom runner, and, when the mould was nearly full, to transfer the ladle to the top of the mould, to finish casting, and then run some slag on the top to keep it fluid as long as possible, and so allow it to feed itself. Ingots cast in this manner, if the metal had been properly melted, were free from blow-holes, but the tops were sunk. The best moulds for heavy ingots were made in halves of ½ inch W.I. or steel plates, lined with 1½-inch bricks, faced with ½-inch of moulding composition, dried, tarred, and the tar burned off; the composition, of course, required renewing for every cast, but the bricks would last from 100 to 120 casts.

The rapidity with which the metal was run into the mould, and the time it stood in the ladle, had a considerable influence on the behaviour of the metal, both under the hammer and in the testing machine. The production of sound mild steel castings was still a somewhat difficult problem for small pieces. With large castings there was no difficulty whatever. The racers for gun-carriages, referred to a few minutes ago, were by no means difficult to cast, nor were the heavy castings, such as slide-beams, &c., for the 110-ton guns. Those could all be cast with steel containing only ·25 of carbon, ·25 of silicon, ·3 to ·4 of manganese, without the slightest blow-hole. They made many experiments to determine the percentage of silicon which might be allowed in an ingot without injuring its qualities, and they found they could go safely up to ·08 per cent. of silicon without interfering with the ductility of the metal, but not beyond that. The ingots were so sound that gun-barrels weighing 11 tons had been forged out of 13-ton ingots. Mr. Riley had spoken as to pouring the metal from one ladle to another in order to get a more regular distribution of elements in the ingot. That was, no doubt, a good thing, but it was merely a simple form of the agitator, to which Mr. Allen had referred some time ago. At the present time he was making small steel castings at the Britannia Works, Derby, many of them only 1 lb. weight, and the heaviest not much more than 1 cwt. The steel was made in a small Bessemer converter, in quantities of half a ton to 15 cwt. at a time. At first it was very difficult to get sound castings, partly because they could not get the metal sufficiently hot; but that difficulty had now been overcome, and the metal was quickly poured into the ladle, and stirred by an agitator. He had first driven the agitator at 100 revolutions a minute, and obtained very little benefit; but by increasing its speed to 360 revolutions much better results were obtained, and many of the castings were perfectly solid. They contained ·4 per cent. of carbon, ·2 of silicon, and ·4 to ·6 of manganese. Mr. Harvey had referred to the absorption of sulphur in open-hearth furnaces; that agreed exactly with his own experience, for on analysing the metal they had often found from ·01 to ·02 per cent. of sulphur more in the finished ingot than the calculated amount in the materials put into the furnace, and in every case the furnace was one in which the gas played on the surface of the metal.

Mr. John Head, in reply, said it was a matter of congratulation that the users of steel were better satisfied with the material than the manufacturers. The users considered that no fault whatever was to be found with steel, but makers, to whom his paper was more particularly addressed, were conscious that there still existed some points which were susceptible of improvement, and that the prevention of blow-holes in the manufacture of steel was a subject worthy of careful consideration. The discussion was very satisfactory, for it showed that manufacturers of open-hearth steel were making progress, improving their manufacture, and delivering a constantly improving article to the users. He thought Sir N. Barnaby could not have been present during the reading of the whole of the paper, for it made no allusion whatever to iron; but he quite agreed with Sir N. Barnaby's remarks, considered independently. In his paper he spoke of steel and glass, and had tried to bring experience acquired in the manufacture of glass to bear upon the manufacture of steel. Glass being a transparent article, they were enabled to see defects which could not be seen in steel. He had exhibited bottles made of glass melted by contact of flame, and others that were made of glass melted by radiant heat, or, in other words, without contact of flame, and the improvement in the product was very remarkable. The inference to be drawn was, that if such improvement could be made in glass melted by radiant heat, the same improvement might be effected in steel made by the same means. In speaking of glass, he said that freedom from blow-holes might be obtained either by fining or by melting the materials without contact of flame, the latter, however, being alone available in steelmaking. He was aware that suggestions had been made for removing gases from steel, and had referred to some of them in his paper, notably to agitating the metal in the ladle, and Mr. Riley's method of using two ladles was very much the same thing, as it depended upon agitation of the metal for such partial success as might be obtained by its use. But he maintained that prevention was better than cure, and if they could avoid getting blow-holes into steel it must be much better than driving out of it the gases which formed the blow-holes, as that operation involved cooling the metal, which was objectionable for many reasons. It was with that object he had brought the subject before the Institute. Beyond that, as pointed out by Mr. Harvey, they had the advantage, in using furnaces heated by radiation, of preventing the absorption of sulphur by the metal which it was liable to take up when the flame came in contact with it. A gentleman from Elswick (Mr. Hardisty) had been good enough to give an illustration of the increase of sulphur he obtained in melting open-hearth steel by contact of flame. With regard to Mr. Hardisty's remark that sound metal was produced by adding ·25 per cent. of silicon, the use of that material for the removal of blow-holes in steel was first proposed, he thought, by Sir Henry Bessemer; this partly succeeded for castings, but it was generally supposed that silicon was not a desirable ingredient to import into very mild steel, and the addition of that material was not generally practised in making such metal.

Mr. Martell and Mr. Parker objected to the inference he had drawn from the Reports he had quoted, and he regretted the circumstance. But they should not find fault with him for endeavouring to solve, by other means than they had used, problems which they had left unsolved. In his paper, the presence of blow-holes in open-hearth steel was dealt with in a definite manner, and there could be no doubt that their absence would be beneficial; but with regard to the theory about the existence of a series of blow-holes forming a line of weakness in plates, it was only given as a suggestion for consideration. Whatever might be the value of that suggestion, considered on its own merits, as revealed by further inquiry, there could be no doubt that if the discussion led to the adoption of microscopic analytical examinations of fractures, which he was not aware had yet been attempted, the suggestion would not have been made in vain, and he hoped that that would be one result of the ventilation of the subject. He wished to thank the meeting for the kind manner in which they had received his paper.

The proceedings were at this stage adjourned until the following day.

FRIDAY, MAY 14TH.

THE proceedings of the Institute were continued this forenoon —Dr. PERCY, F.R.S. (President), in the chair.

PRICES OF STEEL RAILS.

The **PRESIDENT** said it would be remembered that when he had the honour of addressing them a day or two ago, he made a rather startling statement—that a certain German firm would be prepared, if necessary, to supply steel rails at the low price of £3, 3s. per ton. As that statement, unless the meaning of it were thoroughly understood, might produce a mischievous impression on the mind of the British public, he would ask Sir Lowthian Bell to be good enough to say a few words in explanation of it, as he had kindly consented to do.

Sir I. **LOWTHIAN BELL** said, when the President made the statement yesterday respecting the price of steel rails on the Continent, there were two circumstances which presented themselves to his mind—first, that it was incorrect to imagine that steel rails could be made cheaper abroad than here; and, secondly, that it was a mistake to say, so far as he knew at least, that any German houses had expressed themselves in the terms mentioned, namely, that they were prepared to ship rails at 63s. per ton. So far as he knew, something like 73s. was much nearer the price. Mr. Windsor Richards was present, and would correct him if he was in error with regard to that figure. But some persons might be surprised that the German manufacturers could undertake to deliver rails on board a vessel even at 73s. per ton, because it might be inferred that they were really able to manufacture rails very much more cheaply than was being done in England, and could undersell English manufacturers. The fact was, that German and other foreign manufacturers stood in a somewhat peculiar position. They levied, as was well known, a duty upon all rails imported from England. The consequence was, that an English manufacturer had to add to the market value of the rails in this country the freight, say to Germany, which, he supposed, might be taken roughly at 10s. per ton. He had also to add a further sum of 25s., which was the import duty, making, therefore, an addition of something like 35s. to the English price; so that, in the event of a German railway requiring a supply of rails, a German manufacturer had to compete with England on the following terms. He would take the price of the rails, say 75s. or 80s. in England; to that he had to add 35s., which made £5, 10s. to £5, 15s. as the cost of English rails delivered in Germany. At that price the German manufacturers would undoubtedly have a very handsome profit; but, unfortunately for themselves, they had so enlarged their works that they were able not only to supply the whole of their home demand, but, in addition, for every two tons required at home, they were able to make another ton—in point of fact, one-half more than that required for home consumption. The German manufacturers, therefore, would have to consider whether it would answer their purpose better to lay their works in to the extent of 33 per cent., or one-third of the whole production, than to keep them going at a loss on this portion of their make. Of course, all manufacturers were perfectly aware under what disadvantages a concern was kept going when it was not at full work, and partly for that reason, and, no doubt, partly to keep their men together, the Germans prefer incurring an actual loss on the portion of their output which they exported—a loss which was made good by the high price they charged to the home consumer.

The following paper was then read:—

ON WROUGHT-IRON CONDUIT PIPES.

By Mr. HAMILTON SMITH, Jun.

WROUGHT-IRON pipes are largely in use in the Pacific States and Territories of the United States as water conduits; cast-iron pipes are only used for city distributing mains, where frequent connections with service pipes are required. The adaptation of wrought-iron for this purpose was due to the following causes, and affords an apt illustration of the old proverb that Necessity is the mother of Invention.

The method of hydraulic mining was introduced or invented in California in 1852. It may roughly be defined as the discharge of jets of water, actuated by gravity with a considerable head, against a bank of auriferous gravel, the water acting first as an excavator and afterwards as a carrier of the washed material. The supply of water for these jets at first was conducted through hose made of heavy cotton duck cloth, which was strengthened by outer nettings of cordage when the pressure was large. This hose was costly and short-lived. It was not practicable to use pipes made of cast-iron—first, on account of the prohibitive cost of transportation over steep mountain roads and paths to the mines; and second, because heavy cast-iron pipes could not be cheaply and quickly moved from place to place in the mine, the exigencies of such mining requiring frequent changes in the position of the supply pipes.

In 1853 an ingenious miner laid in his mine a line of pipe consisting of joints of ordinary stove-pipe, made of very thin sheet-iron, lightly fastened together with cold rivets, with the joints united stove-pipe fashion, *i.e.*, the end of one joint being tightly shoved into the larger end of the succeeding joint, with the smaller end pointing down stream. This experimental pipe was some 5 or 6 inches in diameter. The pipe answered the desired purpose admirably, and in a comparatively short time all the many hydraulic gravel mines in California obtained the pressure for their water jets by means of thin sheet-iron pipes. As hydraulic mining increased in magnitude the sizes of these supply pipes also increased, the diameter for main lines for a large mine being from 22 to 30 inches. These pipes, as a rule, are made at the mine, the requisite machinery costing less than £100. The iron is from ·065 to ·134 inch (Nos. 16 to 10 Birm. gauge) in thickness, with a double row of cold rivets for the longitudinal seam when the pressure is to be large. The only test made of the quality of the iron is the judgment of the pipe-maker, who can generally discover and reject sheets of bad quality by defects manifested when the plates pass through the rolls; in fact, this is one of the chief reasons why the mine-owners have preferred to make the pipes themselves. The length of the separate joints is from 18 to 25 feet, one end being slightly smaller than the other end. As a protection against rust each joint is immersed for several minutes in a bath of boiling asphaltum and coal-tar; a little rosin is added when a glassy surface is desired, and sometimes a little fish oil. This immersion results in a thorough coating of the pipe, both inside and outside, and is vastly superior to any application of paint. When the pipes are coated properly the protection appears to be perfect. The several joints are then joined together, stove-pipe fashion, the lower joint being shoved firmly into place by jack-screws. When the fit is slack a piece of tarred canvas is wrapped around the small end; wedges of soft pine wood are sometimes driven in where the fit is a bad one. Such pipes are laid on the surface of the ground, and can be put together or taken apart with great ease and at small expense. When a line of such pipe is laid by skilful men with ordinary care, although the length may be several thousand feet with a pressure at the lower end as great as 450 feet, there are but trifling leaks, which generally can be stopped by putting sawdust into the inlet end of the pipe. As an illustration of the tightness of such rough joints, I may instance a main laid by me for supplying water power, having a length of two miles and a maximum pressure of 550 feet. The leakage from this pipe did not average more than 3 or 4 cubic feet a minute, although the only protection from changes of temperature was a couple of boards tacked together and placed over the pipe.*

---

* The extreme range of temperature was from 10° to 107° Fahr. (in the shade).

After successful practice in the mines had demonstrated the advantages and capabilities of wrought-iron pipes, they were used for permanent conduits both for conducting water to mining districts across deep mountain gorges, and also for the supply of cities. San Francisco, a place of some 300,000 inhabitants, receives its water through two lines of such pipes, and a third pipe, many miles in length and of large diameter, is now being laid for an additional supply.

For permanent conduits the joints of a pipe of considerable diameter are generally riveted together; for small diameters with high pressures lead joints are used. Such conduits are, of course, placed in trenches, and covered with earth in order to avoid excessive alternations in contraction and expansion; slip-joints need not be used, as the pipes are sufficiently elastic to permit changes in length due to variation of the temperature of the water.

The following statement will illustrate the Pacific Coast practice with conduit pipes, the flow in all cases being caused by gravity:—

Name.	When laid.	Length in feet.	Diameter in inches.	Maximum pressure in vertical feet of water.	Maximum tensile strain in lbs. on iron per sq. inch.	Description of pipe.
Cherokee	1870	12,798	30	887	17,549	Plate iron, double riveted.
Virginia City .	1872	37,100	11	1720	about 15,000 (?)	Plate iron, double riveted.
	1873	37,100	10	1720		Lap-welded tubing; outer screw couplings.
Texas Creek .	1878	4,439	17	760	about 18,000	Plate iron, double riveted.
Humbug	1868	1,194	26	120 (?)	11,500	Single riveted iron $\frac{1}{16}$ inch in thickness; two pipes each 26 inches diameter, laid side by side.

The two Virginia City pipes are laid side by side; the lead joints for the riveted pipe under the enormous pressure of 1700 feet at first gave considerable trouble; the lap-welded pipe gave no trouble whatever. The general tensile strain on the Texas Creek pipe is about 16,500 lbs. per square inch.

The oldest of these pipes—the two across Humbug Cañon—are notable for having been laid seventeen years ago of iron single-riveted only $\frac{1}{16}$ inch in thickness; when I last heard from them, a few months ago, they were reported to be in good order. The other pipes are also stated to be now in excellent condition.

The iron for the Virginia City and Texas Creek riveted pipes was of very inferior quality; the iron for the Cherokee pipe was of ordinary quality; yet it will be observed these pipes have for many years past been subjected to tensile strains which must seem almost fabulous to one only accustomed to cast-iron water pipes.

So far as rust is concerned, in my extensive experience I have only seen one notable instance where an asphaltum coating properly applied did not protect the iron, and that was with a pipe over which passed a stream of water highly charged with sulphate of iron. I may also remark that when iron has once been attacked with salt rust from sea-water, it seems to be very difficult to prevent further rust.

The California experience with double-riveted pipe, made of a superior article of plate iron, can thus be summed up:

Such pipes can be with entire safety subjected to a constant maximum tensile strain of 16,000 lbs. per square inch.

For a period of twenty years an asphaltum coating has prevented rust, and also the formation of interior tubercles where soft water flows through the pipe.

Lap-welded iron tubes of sizes up to 15 inches in diameter are now largely used in the United States for conduit pipes, and will safely stand a strain of about 20,000 lbs. per square inch. They are almost exclusively used in the Western mines for pump columns, owing to their combined lightness and strength. The lines of pipe through which petroleum is pumped from the Pennsylvania oil-wells to the sea-board are made of this tubing, the diameter generally being 6 inches.

The query presents itself, Why should not wrought-iron, or still better steel, be used for conduit pipes in preference to cast-iron? If it answers the desired purpose in California, why should it not do so in other parts of the world? To one like myself, who has for years been accustomed to the California practice, it seems as irrational to build a pipe carrying water under considerable pressure of cast-iron, as it would be to build a suspension-bridge with the supporting chains made of cast-iron.

Experience in the United States has shown that the practicable limit of size for cast-iron mains is a diameter of about 4 feet, even when the pressure is less than 100 feet. It is evident that a pipe of wrought-iron or mild steel can be safely made of almost any desired size, and this may be of much advantage if it be desired to conduct a large supply of water through pipes for city or other use. For instance, with an inclination of 3 feet per mile a single pipe 8¼ feet in diameter will carry 280 cubic feet per second, while seven pipes, each 4 feet in diameter, would be required to transport the same quantity of water with the same inclination. The cost of the large pipe, made of steel or wrought-iron, would be considerably less than one-half the cost of the seven small pipes made of cast-iron.

The ideal conduit for high pressures is a welded steel tube; such tubes could probably be subjected to a tensile strain of 25,000 lbs. with perfect safety, and would be much preferable to riveted pipe, not only on account of superior strength, but also by reason of almost perfect interior smoothness.

It seems to me that this question is well worthy of the attention of British steel-makers and hydraulic engineers. The adaptation of a superior and cheap metal such as mild steel for conduits, will permit the construction of hydraulic works in many parts of the world which now appear to be impracticable, owing to the cost of many of the methods still in use for the transportation of water.

DISCUSSION.

The PRESIDENT said he had great pleasure in proposing that the thanks of the meeting be tendered to Mr. Hamilton Smith for his interesting and important paper.

The vote of thanks having been given by acclamation, the President invited discussion.

Mr. J. RILEY said he had listened to Mr. Smith's paper with considerable interest. This matter of steel conduit pipes had been before his company several years. He believed Mr. Russell Aitken, who addressed them yesterday with regard to the vacuum-pan—if it might be so termed—for removing blow-holes, was at one time Resident Engineer for the municipality of Bombay, and about seventeen years ago he proposed to that municipality a very extensive water scheme, to bring water a considerable number of miles down to the city of Bombay. In that scheme he proposed to make the water-main of steel. That was the earliest instance he knew of such a proposal. It was looked upon as rather a mad scheme, he believed, by a good many people, so that it hung fire, and only during the present year the municipality had decided to extend its waterworks, and had gone in for a cast-iron main, which was undertaken by a Glasgow firm lately. Four or five years ago a paper was read before the Institution of Engineers in Glasgow by a gentleman who had visited the United States. In that paper he detailed a good many instances which Mr. Smith had just laid before them. A few years ago his (Mr. Riley's) firm was visited by some gentlemen from New York. That was the first time that this matter was brought before him. They had before them a scheme for a water-main to increase the supply of water to New York City, and the main was, he believed, to be ultimately eighty miles long, but at that time it was proposed to be only forty miles. He went into the matter carefully with them, and prepared estimates as to the cost, and made all arrangements for supplying the main, if required, and if the scheme was completed. About 30,000 tons of steel would be required for the making of that main. It had not yet come to business; but under the guidance of one of these American gentlemen they made 100 tons of pipes, 16 inches in diameter, and one-sixteenth of an inch thick, which they sent out to the Central States of America for the very purpose that Mr. Smith had referred to. Subsequently, or just about that time, there was talk of a large main for New South Wales. He called upon the engineer—who was present at the meeting yesterday or the day before, intending to speak on this subject—and proposed to him that that main should be made of steel, and he would undertake to make it, supply it, ship it, and deliver it in New South Wales at a considerably lower cost than he could have it made of cast iron. He believed that, eventually, a portion of that main was constructed of wrought iron, and he did not know if it was yet finished. Following that came the Bombay scheme, which he had just referred to, and which he tried again to turn in the direction of steel, but failed; and, last of all, he had worked constantly on the largest scheme of its kind that had been heard of in this country, and which was settled only a few months ago, namely, the scheme for the supply of water to Manchester from Thirlmere. (He should have stated, as bearing out what Mr. Smith had said, that several of these mains were five feet in diameter.) He submitted to the engineer of that scheme a proposal to make the main, and suggested that it would be very much cheaper, and a more economical scheme for the Manchester Corporation to have that main of steel than to adopt cast iron. He failed, however, on one single point. The proposal was nearer being completed than any of the others to which he had referred. It failed because they wanted experience of how the pipes would stand in the matter of corrosion. If he could have pointed to any experience to remove their doubt on that point, or if the engineer could have taken the responsibility, he believed they would have had an example in this country of the largest steel main ever constructed. He thought the members would like to know how this matter had been treated in England.

Mr. E. A. Cowper said, perhaps it would be interesting for him to mention that the Kimberley Waterworks had a 14-inch main, only a quarter of an inch thick, of wrought iron welded tubes, 18 miles long, and it had proved most satisfactory.

ON THE APPLICATION OF VERY HIGH POWERS TO THE STUDY OF THE MICROSCOPICAL STRUCTURE OF STEEL.

By H. C. SORBY, LL.D., F.R.S., &c.

Though I had studied the microscopical structure of iron and steel for many years, it was not until last autumn that I employed what may be called *high powers.* This was partly because I did not see how this could be satisfactorily done, and partly because it seemed to me unnecessary. I had found that in almost every case a power of 50 linear showed on a smaller scale as much as one of 200, and this led me to conclude that I had seen the ultimate structure. Now that the result is known, it is easy to see that my reasoning was false, since a power of 650 linear enables us to see a structure of an almost entirely new order, and of such a character that, if it had been on a scale of a quarter or a half the actual magnitude, it would probably never have been recognised, on account of being beyond the resolving power of the microscope for fine parallel lines.

The illumination employed is that contrived many years ago by the late Richard Beck, and consists of a thin plate of glass adapted above the object-glass, inclined at an angle of 45° to the axis, reflecting light down through the object-glass, which acts as its own condenser, and transmits freely enough the light passing back again to form the image in the eye-piece. With this arrangement, high powers give as good, or even better, illumination than low. Speaking generally, a power of 650 linear is about ten times that previously employed, which is, of course, enough to open out a new field for research. This great increase has, however, shown little or nothing more in the case of malleable iron containing little or no carbon, or in the case of the intensely hard constituent of spiegel iron, of white refined iron, and of blister steel. It has also shown but little more in the case of enclosed slags, or of the graphite in cast iron; but it has enabled me to see to great perfection crystals which are probably silicon, and has thrown a flood of light on the nature and character of that constituent of steel which in my lecture at the last annual meeting I described as the *pearly* compound. High powers show that it really has a structure closely resembling that of pearl, the surface being marked by fine straight or curved parallel lines, due to the presence of alternating very thin plates of varying hardness. After only a few hours of observation, I felt almost certain that these thin plates were iron free from carbon, and the intensely hard substance seen so well in blister steel; but the facts were so extraordinary, and so unlike anything I had ever seen or heard of in any mineral substance, that it was not until after several months devoted to the careful study of all the chief kinds of iron and steel that I felt confidence in the results.

The chief facts are best seen in the case of an ingot of steel of medium temper. On fracture, comparatively large crystals are visible, radiating from the surface to the interior. When a properly prepared microscopical section is viewed with a moderate power, it is easy to see that, after having crystallised out from fusion at a high temperature, these large crystals break up on further cooling into much smaller, as described in my lecture. What is now seen with very high powers is that these smaller crystals finally split up into alternating very thin plates. Taking all the facts into consideration, it appears as though a stable compound of iron with a small amount of carbon exists at a high temperature, which at a lower breaks up into iron combined with a larger amount of carbon, and into iron free from it. If these two products had not differed so much in hardness, or if the alternating plates had been considerably thinner, or if definite plates had not been formed, such a compound structure would never have been suspected. It has probably never been specially looked for in other substances, and might exist without being visible, even with the highest and best magnifying powers.

In those cases where no subsequent segregation has occurred, these alternating plates are often remarkably regular and uniform in thickness; and, as far as I am able to judge, the softer plates are about double the thickness of the harder. If so, we may say that the thickness of the softer plates is about $\frac{1}{10,000}$th of an inch, and of the thinner $\frac{1}{80,000}$th, thus giving well-marked stria $\frac{1}{60,000}$th inch apart. To define even these requires very careful adjustment of the object-glass; and considering all the circumstances of the case, it could not be expected that the two bounding edges of the thinner hard plates could always be defined, so as to show a flat intermediate surface. We are, in fact, brought face to face with an optical difficulty, depending on the considerable length of waves of light compared with the objects under examination, and are obliged to infer the nature of the very finest structure from what is seen when it is somewhat coarser. In some cases it is easy to trace the gradual passage from these extremely thin plates up to those which are sufficiently thick to show clearly that the structure is due to thin plates of the hard substance between soft iron. No mere cleavage would explain all the facts, though it is extremely probable that the direction of the alternating plates was determined by the previous crystalline structure. In some cases the plates are less well marked and the structure is more granular.

To give a good idea of the size of the plates, I would refer to what is seen in a longitudinal section of medium steel forged from an ingot 3 inches in diameter down to a bar 1 inch square. When broken, it shows a very fine grain; and when a prepared section is examined with a moderate power, this grain is seen to be due to crystals often about $\frac{1}{1000}$th inch in diameter, which are not drawn out or distorted, as they would have been if they had existed previously to final cooling after hammering, and as they are distorted if the steel be hammered at a lower temperature. Examined with a power of 650 linear, these crystals only $\frac{1}{1000}$th inch diameter are seen to contain something like 60 of the alternating plates, and even this extremely delicate structure shows little or no trace of distortion. Of course it is impossible to separate and analyse such thin plates, and we must rely on induction to furnish us with a knowledge of their nature. My reason for concluding that the hard plates contain combined carbon is that they are not seen in iron free from carbon; they increase in amount with increase of carbon, and are seen to the greatest perfection when there is a considerable amount in a combined state. With an increased amount of carbon, comparatively large more or less solid plate-like crystals of the hard compound may be formed before the rest of the steel crystallises, or the excess of it thrown off to the surface of the crystals. In partially decarbonised white cast iron the thin plates are sufficiently thick to show perfectly well that the hard plates are continuous with portions of the original hard white constituent, and the soft plates continuous with the soft malleable iron free from carbon produced by decarbonisation. These two substances differ very greatly, and apparently are perfectly stable both at a high and a low temperature, whilst the facts already described show that an intermediate compound exists at a high temperature, and, under certain conditions, easily breaks up into a mixture of the other two at a lower.

The relations of this unstable compound to all the different kinds of iron and steel is too complex to be described now, but I may say that, when no graphite is present, a long-continued moderately high temperature may cause the two constituents to segregate into comparatively thick and irregular plates of the hard compound and aggregations of free iron; whereas when graphite is present, the combined carbon appears to be set free, crystallising out as graphite and leaving free iron. This is one of the most important differences between steel and cast iron.

It also seems to me that this remarkable constituent probably plays the chief part in the hardening of steel. What I have been able to see with high powers shows that when strongly reheated the constituents again combine, and when suddenly chilled there is no evidence that they separate, though it is *possible* that this may be because the particles are too small to be separately defined. It, however, seems to me very probable that in the hardening process the unstable compound may not break up into soft iron and the very hard and brittle substance, but may be suddenly fixed, so as to give great hardness combined with strength. According to this view, the peculiar properties of Muschet's self-hardening steel may be due to the presence of tungsten preventing this usual separation. That the softening of hardened steel depends on a separation of the two constituents seems proved by what is easily seen when the heat has been maintained for a considerable time. In attempting to solve these questions, it is quite clear that we shall have to face difficulties depending on the comparatively coarse structure of light itself.

Allowance must also be made for mechanical imperfections in my preparations, though, strange to say, these do not seem to be anything like so important as might have been expected.

The only other point to which I need now refer is the presence in some samples of cast iron of numerous very perfect and beautiful crystals of a kind invisible with low powers, being usually less than $\frac{1}{1000}$th inch in diameter. They differ entirely from the comparatively large, somewhat irregular, plate-like crystals of graphite, though they sometimes occur in them. Some are of a beautiful ruby colour, and others of a peculiar dark hue. The usual forms are triangles, rhombs, hexagons, and complex crosses. All seem to be modified conditions of the same substance. I have never seen anything like them in bar iron, and they are almost, if not quite, absent from good cast steel. Though further evidence is needed, yet, taking everything into consideration, it seems to me most probable that they are two different crystalline modifications of silicon. With high powers, some specimens of cast iron are seen to be complex mixtures of different substances, analogous to natural rock composed of several minerals. Some of these substances are almost or quite absent from cast steel, which has a comparatively simple constitution.

It will thus be seen that the use of very high magnifying powers opens out a wide field for research, and has already placed a number of important questions in a new light. As far as I am able to judge, all the facts seen in the various kinds of iron and steel hitherto examined may be explained in accordance with the views here described; but the time spent in studying the fundamental questions prevented me from finishing a comprehensive illustrated memoir which was already in large part written before using very high powers.

DISCUSSION.

The **President** said that, having expressed only a day or two ago the strong opinions that he had formed of the value of the researches of his friend Dr. Sorby, he thought he need not add anything more. What Dr. Sorby had stated on the present occasion had more than justified the remarks that he (the President) had ventured to make. He did not wish to obtrude his own opinions on their attention, as he knew that there were several gentlemen present who had devoted themselves specially to microscopical observations, and perhaps one or more of them might be induced to say something with respect to the paper.

Sir **Henry Bessemer** said he had listened, as he was sure every person present had done, with intense interest to the paper that had just been read. The subject of the crystallisation of malleable iron, and the milder sorts of steel, which approached very near to malleable iron, was one of immense importance. He thought, when they came to study that part of the question more than the mere mechanical parts which had hitherto occupied so much of the attention of practical men, they would find a new light break in upon them, which would, probably, considerably modify their operations. He would refer to an experiment that he made some thirty years ago on the crystallisation of fluid malleable iron. Perhaps they would more easily understand what he was going to refer to if he gave a familiar example with which they were all well acquainted, namely, the crystallisation of ordinary loaf-sugar, in which they had a tolerably bold crystallisation, something like that in No. 1 pig iron. The French preferred a very fine-grained sugar, that melted rapidly in cold water, and they would stir the sugar in the mould so that it should rapidly cool and crystallise and form small confused crystals. But the maker of sugar-candy kept his solution hot for a fortnight, and by that means developed crystals of considerable size, although they were easily detached from each other. Here it would be seen that the same substance as the French sugar, with its fine grain, like cast steel, could, by slow cooling, be formed into a huge crystal, such as they unfortunately too often found in some of their big forgings that had been kept too long hot in the furnace. He was most anxious, at the time he mentioned, to ascertain if the crystallisation of malleable iron would take place in large and well-defined crystals, like sugar-candy, if he could only keep it hot for a sufficiently long time to allow them to develop. For that purpose he had an opening made in the ground and lined with brickwork, some 5 or 6 feet square, and a depth of 7 or 8 feet. This was filled up with moulder's sand, and he moulded in it a large ball such as was commonly used by founders for breaking pig iron. Leading down to the mould, some 4 feet from the surface, was a small tubular opening, about 3 inches in diameter. When the moulding operation was completed, charcoal was put into the hollow mould, and a suitable pipe conveyed a forced blast of air down into it for a space of about two days and nights; thus the fire was kept up until the heat had penetrated far away into the huge mass of material surrounding the mould. When the whole of the charcoal was consumed, the blast was taken off, and malleable iron made by his process was poured into the red-hot mould, and then hot sand was put down the long tube until the opening was filled. Thus there were no means for the escape of heat, except through the large mass of highly heated sand forming the mould, and the time necessary to develop large crystals was thereby obtained. After ten days, the large spherical mass was taken out, and was found to consist of nearly pure malleable iron, with a rather heavy dose of phosphorus and very little carbon, as proved by analysis. When the mass had been quite cooled down, he thought of cutting it in two with the planing machine; but he first tried the sledge-hammer, and the mass, which was about 14 inches in diameter, came in two with a few heavy blows. The whole surface was divided into cubes, having smooth, bright faces, of a quarter, and some of three-eighths of an inch square. The cohesion between the respective crystals was so feeble that, taking up a mass such as that before him, and holding it in the hand, he could with a little two-pound hammer knock off a shower of crystals, a dozen or two adhering together, while others were separate and detached. Some of these cubes were like little dice. On placing one of them cold on the anvil, and giving it three or four successive blows, it would flatten down into a nearly circular plate the size of a sixpence, and equally thin, showing slight cracks only at the edges, and proving that each crystal was perfectly malleable; but their cohesion was so feeble that, as a mass, it was useless for any purpose whatsoever. He had alluded to that fact in order to show how very much of the results obtained in their steel castings would depend upon the time of cooling and the heat of the mould; and he had no doubt, also, that much of the metal that was forged under the hammer, or was rolled into bars or plates, would vary in quality according to their crystallised structure. He thought the facts that had been brought before them by Dr. Sorby served to illustrate the immense importance of a further study of the subject.

The PRESIDENT begged to propose that the best thanks of the meeting be presented to his friend Dr. Sorby for his most admirable paper.

A vote of thanks having been accorded by acclamation,

The PRESIDENT announced that the next paper to be read was one by Mr. F. W. Webb, on "The Endurance of Steel Rails." He regretted to say that Mr. Webb could not be present on this occasion. He would, therefore, call upon the Secretary to read the paper which Mr. Webb had communicated, and which, though short, contained material of great value, especially from an economic point of view.

The following paper was then read:—

ON THE ENDURANCE OF STEEL RAILS.

By Mr. F. W. WEBB, Crewe.

As a great many questions have been asked me as to the comparative durability of iron and steel rails, I have thought that the nineteen years' results on the London and North-Western line of railway, which I have been able to tabulate, might be of interest to the members of the Iron and Steel Institute, and I beg to submit a diagram to this meeting showing the comparative numbers of tons of iron and steel rails used for relaying purposes on the railway in question, from 1867 to the end of this year, the last year being, of course, the estimated requirements.

On the same diagram I have shown the quantity of coal burned yearly in the locomotives, as I take it that this is the only reliable way in which we can arrive at the amount of work done on the line in each year; and, as a check upon the coal consumption, I have also shown on the diagram a line representing the train miles along with the engine miles. It will be seen at a glance, that while the coal line very closely follows in proportion to the train miles and the engine miles run in each year, the quantity of rails used for renewals has been a constantly decreasing amount since 1877.

From 1868 to 1877, we were putting down both iron and steel rails on renewal account. I have shown the iron and steel rails separately in the diagram, and the combined iron and steel in a double line. It will be noticed that in 1868 the quantity of iron and steel rails required for renewals was, roundly, 16,400 tons, and that the largest weight of rails required for renewals was arrived at in 1876, twelve months after which iron rails entirely disappeared—the total number of tons used in that year (1876) being 31,391, while the estimated requirements for this year are only 11,600 tons.

Practically, the whole of our main lines are relaid with steel; and while, in past years, we have been putting down steel rails as fast as iron ones have become worn out, we are now putting down steel rails as fast as steel rails wear out, except on some of our branches, where iron rails, of course, last a much longer time than on the main line.

From what I can see, by watching closely our own line, I believe we have now reached the minimum required for renewals, and that our renewals will rather increase than otherwise, but at a much less rapid ratio than they did up to 1876.

The small quantity of rails required for renewals on the London and North-Western railway, if other companies have relaid their roads with steel at anything like the same rate, will account in some measure for the depression in the steel-rail trade; and, as our steel rails wear out, the quantity of pig iron required to keep the road going will be represented as nearly as may be by the difference in weight between the rails when put down and when taken up for renewal, plus 7½ per cent. for loss in remanufacture.

This will also represent very closely the quantity of iron required for the bath in the Siemens' furnace for re-melting the old steel rails, so that, for a considerable period, the quantity of iron required on such a line as ours will be much less than it has been during the past period; but, if steel sleepers are found to answer, and I see no reason why they should not, I hope they will in a great measure fill up the want of orders for steel rails in our various large works.

On our main line, up to the present time, we have put down 45,000 steel sleepers; and, on recently examining those we first put down on the Chester and Holyhead line six years ago, I found that they were in very good order, with no signs of loose rivets, though they were made with a much less chair base and leverage for the rivets than the sleepers we are making now.

While on the subject of steel sleepers, I may observe that there has been a good deal of discussion, and a number of questions have been asked me, as to their tendency to work endwise, especially in curves; but, so far as our experience goes, when properly ballasted up, we do not find this tendency. Our engineer, Mr. Bradford, who has had some of these sleepers down for a considerable time in our South Wales district, on gradients of 1 in 38 and on a curve of 10 chains radius reversing into one of 15 chains radius, finds no tendency to working endwise; and while going over the road previously referred to in North Wales with some Scotch engineers, I pointed out to them many cases in which moss was growing on the end of the sleeper and on the ballast without the slightest sign of disturbance. As it may interest the members of the Iron and Steel Institute to see the present form of the steel sleeper and chair, I have ventured to send one for inspection at the meeting.

The **President** said he had great pleasure in proposing that the thanks of the meeting be conveyed to Mr Webb for his valuable contribution.

A vote of thanks was accorded to Mr. Webb by acclamation.

ON A NEUTRAL LINING FOR METALLURGICAL FURNACES.

By M. FERD. GAUTIER, Paris.

The discovery of the refractory properties of certain materials was an immense help to the industry of the world, and in metallurgy, where the highest known temperatures are employed, and the chemical actions are of so various a character, the study of *refractory materials* is especially of the first importance.

It is only within the last twenty-nine years that real progress has been made in this direction. Formerly, only one kind of brick was known with refractory properties, viz., the *clay brick*, of which the best type was the *Stourbridge*, containing per cent.:—

Silica	63 to 67
Alumina	29 ,, 31
Peroxide of iron	3 ,, 6
Potash, soda, &c.	0.7 ,, 2

Andenne in Belgium and *Bollene* in France produced the other qualities of firebrick, which were about equivalent in quality to the Stourbridge.

The material of these *clay bricks* was generally an artificial mixture of clay and silica. The *silica* was never under 50 per cent. From a chemical point of view they were of a silicious nature, and, of course, their action was what is called *acid*.

In metallurgical processes, bricks are used for *linings, beds of furnaces*, and *hearths*, which must be without mortar joinings, and, as far as possible, made of a solid and homogeneous mass. *Silicious sand* has answered well for this purpose. The hearths of our heating furnaces in the iron and copper industries are all of this character,—that is, essentially *acid*.

I might mention the Dinas or *silica* bricks as an important development, especially for the Siemens furnace. Instead of shrinking, like clay bricks, silica bricks expand by the action of heat, and are thus the best adapted to the roofs, whose stability increases with the temperature. Exceptionally, and for special purposes, carbon or graphite is employed as a refractory material. A mixture of tar and coke-dust was employed with success by Henderson for the hearth of the Siemens furnace, producing spiegel with 25 per cent. of manganese, and also by the Terre-Noire Works, for the manufacture of ferro-manganese. These materials are of a highly *reducing* character, and could be largely employed, if their principal constituent—carbon—was not so easily burned.

In another direction, *oxide of iron*, as the lining of the hearth of the puddling furnace, was a great improvement in the manufacture of wrought iron. Its action, as is well known, is essentially *oxidising.*

Such, in a few words, were the refractory materials used in metallurgy when the important question of *dephosphorisation* came to the front. The impossibility of retaining in an acid slag the phosphoric acid generated by a strong oxidation in the process developed the use of refractory *basic* materials.

Magnesia and burnt dolomite are the materials which have enabled this metallurgical process to succeed.

My present object is to call your attention to a perfectly neutral refractory material, which is neither *acid, basic, reducing,* nor *oxidising,* but which, when properly employed, may be very useful for furnace linings.

Chromite or *chrome iron ore* is a chemical combination of oxide of chromium and ferrous oxide—FeO,Cr_2O_3.

In some varieties, a part of the Cr_2O_3 is replaced by Al^2O^3, and perhaps Fe_2O_3; whereas more or less lime, ferric oxide, or magnesia, is substituted for ferrous oxide according to the laws of *isomorphism.* Silica, in the form of quartz, and silicate of magnesia (serpentine) are also found intermixed with chromite.

Chemically speaking, chrome ore is very hard to dissolve.

Acids have no action upon it; potash and soda attack it, with the aid of atmospheric oxydising action, and convert it into alkaline chromates or bichromates.

Carbon has, at a high temperature, a reducing action on the chromite, and the result is an alloy of iron, chromium, and carbon, which is now practically employed, especially on the Continent, under the name of *ferrochrome*, in order to impart to steel the important properties of hardness and toughness.

An interesting feature of the reduction of chromite in the blast furnace is, that in case of deficiency of heat, no part of this mineral goes into the slag in the form of silicate, as is the case with manganese in the spiegel or ferro-manganese industry. The unreduced chromite makes a scaffolding, and causes difficulties in the working, which show clearly that chromite is not fluxed by silica, whether free or in the condition of silicates.

A piece of chromite remains, with its sharp edges, floating on the bath of melted steel in a Siemens furnace, without any alteration.

Form a physical point of view, chromite is essentially refractory. Heated in lumps, it does not crumble to pieces, however high the temperature. In general metallurgy, where no alkalies in notable quantities are present, chromite is a refractory material of a specially *neutral* character.

Chrome oxide has for many years been thought of as a refractory material, but it was the chrome oxide of the laboratories—a green substance, obtained in powder at a very high price, and difficult to bring to a compact state in bricks or blocks.

A process was some time ago devised, for making chrome oxide, by heating a mixture of chromite, limestone, and sulphur, and lixiviating the product with water and hydrochloric acid. The object was to produce a refractory material for the open-hearth steel manufacture, but the idea was never carried into practice.

The first trial of chromite in a natural state, as a refractory material, was made in 1879 by M. Pourcel. This was followed, in 1880, by its employment on a large scale at the Petersburg-Alexandrofsky Steelworks, which were under the technical superintendence of the Terre-Noire engineers.

In the basic open-hearth process the roof is always composed of Dinas or silica bricks, whereas the walls of the furnace must be basic. The result is that a critical point is found at the contact between the acid and the basic material. This difficulty was overcome by introducing at that point blocks of chromite. The successful application of this practice was kept a secret until M. Lundgren, the manager of the Siemens furnaces of Alexandrofsky, on retiring, gave full information on the subject to M. Tellander, for publication in the *Jern Kontorets Annaler* (1882). The communication so made was translated into German (*Stahl und Eisen*, vol. ii.), and, having myself no reason to remain longer silent, I explained the features of this practice, with a view to establish the credit of the French metallurgists, in the *Génie Civil*, vol. iii. 1882–83. At the International Inventions Exhibition, last year, a good sample of this material could be seen in the exhibit shown for the Brymbo open-hearth steelworks by Mr. Gilchrist, the result, I believe, of what he had seen at Alexandrofsky.

A new use of chromite in metallurgy was found by MM. Valton and Remaury, and is now adopted in practice. It is the consequence of the *chemical inertia* of chromite in contact with the melted metallic materials or silicates. Since chromite is highly refractory, and cannot be fluxed by silica, why should it not be a constituent of furnace hearths and walls? The prime cost of this substance, though relatively high—about £4 a ton—does not interfere at all, since the wear and tear is trifling. We thus get a kind of crucible, which plays about the same part that platinum does in laboratories. The chromite is employed in two shapes—in lumps, and in mortar with lime. In lumps, chromite, in its natural state, is without distinct crystallisation, and very hard; it can, however, be cut easily enough to be shaped for masonry purposes.

The varieties of ore found in a crumbling state are crushed into dust, in order to form a mortar with lime. It is easy to understand that lime, by its basic nature, can have an action on the chromite; but this action, although strong enough to agglomerate together the small particles of chrome ore, cannot go farther, and never fluxes the material.

The following analyses show the limits within which a chromite is good for this purpose.

	1.	2.	3.	4.
Chrome oxide	51·23	62·20	53·00	37·29
Protoxide of iron	36·63	28·10	27·46	33·00
Alumina	3·17	2·19	12·10	20·70
Silica	1·87	2·60	1·90	3·00
Magnesia	3·79	1·10	...	...
Lime	5·10	3·07	...	...

Practically, there must be more than 37 to 38 per cent. of chrome oxide and less than 6 per cent. of silica. The percentage of alumina seems to be unimportant.

The following mixtures could not be suitably employed, owing to the percentage of oxide of chromium being too low, or that of silica too high:—

	1.	2.
Chrome oxide	30·28	32·3
Protoxide of iron	37·19	43·9
Alumina	19·20	16·0
Silica	8·79	8·0
Magnesia	7·10	...
Lime	3·00	...

In some parts of the furnaces, where there is no fear of oxidation, a mortar of tar and dust chrome ore can be employed with success. When oxidation is to be feared, as in the walls, the tar would be burned, and, no binding material remaining between the particles of chrome ore, the structure would fall to pieces. This is the explanation of some failures which have happened with chromite when not employed in the proper way. To stop up the tap-holes of furnaces, a mixture of tar and chromite is successful, because the tar, changed into coke by contact with the metallic bath, is protected against burning.

In open-hearth practice lumps of chromite are employed, with a lime cement, together with some other description of walls, for the melting of wrought iron scrap, mixed with pig iron, or of pig iron, wrought iron, and iron ore. The product is a very soft steel.

Amongst the works where such open-hearth practice with chrome ore is carried on in France are—

Commercy (Meuse).
Blagny (Ardennes).
Morvillars (Territoire de Belfort).
Tamaris (Gard).

Some applications of chrome ore hearths are now contemplated for other industries.

In copper refining, it is difficult to get rid of antimony and arsenic, owing to the tendency of these impurities to form metallic acids (antimonic and arsenic acid), which cannot remain in a silicious slag; whereas, by an addition of limestone in a *neutral* furnace, whose hearth and walls would be made of chrome ore, antimoniates and arseniates of lime could go off in a basic slag. There appears to be some analogy in the case of the retention of phosphorus with an acid lining, and its easy expulsion with a basic one.

In the metallurgy of lead some improvement may be hoped for with chrome ore hearths.

DISCUSSION.

The **President** said he had listened to the paper with great pleasure, as he was sure all present must have done. It was a very short one, but was clearly expressed, and contained several facts of great interest and of no small practical importance. If he misunderstood not, there were some gentlemen present who had had experience with regard to the use of chrome iron ore, and he hoped they would favour the meeting with their results. He knew that in respect to certain other points mentioned in the paper there were gentlemen present well competent to express an opinion. He had great pleasure in proposing that the thanks of the meeting be tendered to M. Gautier for his capital paper.

Mr. **Windsor Richards** said that he had used chrome ore for lining the basic converters at Eston for some few years past. He tried it at the instance of Mr. Henry D. Pochin, one of the directors of Bolckow, Vaughan & Co., who had patented its application, not only in England, but on the continent of Europe. The patent was taken out some years ago. The reason why they were not lining the basic converters altogether with this chrome ore in its natural state was the difficulty of obtaining it. It was most difficult to obtain it in lumps large enough to dress to lie nicely in the converters. They had lined almost the whole bottom walls of the converters, putting in these lumps of ore, and ramming the ordinary dolomite lining round them. The chrome ore lasted a very long time. The dolomite melted tolerably quickly away from it, leaving the chrome lumps projecting beyond the dolomite lining of the converter for several weeks, and it was only when there was no more dolomite to protect them that the lumps fell out and were lost, otherwise the chrome seemed to last indefinitely. He had just heard from Mr. Pochin that he believed in a very short time he would be able to get this chrome ore in sufficient quantities, and in suitable sizes, to enable them to line the whole of the converter. When that was done it would be a very great advantage, and a very great step in advance, and his belief was that they might work six months at a time without relining.

Mr. J. **Riley** said that, with reference to the open-hearth furnaces, he had never used the lumps in the sense described by Mr. Richards; but in 1880, after the trial of the basic lining dolomite in one of the Siemens furnaces at Newton, Mr. Packer proposed to him that they should make bricks of chrome iron ore, and line the furnace with those bricks. It was not done at that time, but recently they had had a good deal of experience with the use of them, making the bricks pretty nearly in the way that M. Gautier had spoken of, and for two reasons—first, that they could not get the pieces of chrome ore of a size sufficient to cut up, as Mr. Richards had explained. They therefore sought to have the material in the form that they could best use it in the furnace. It had proved very refractory, very satisfactory, but in working, in the cases where they had tried it, the bricks were not made quite in the way that M. Gautier had described. Tar was used, not lime, and a very small proportion of a fluxing material, and they answered very well.

Professor **Huntington** said that some years ago he made a very considerable number of experiments in a somewhat different direction—endeavouring, in fact, to extract chromium from chrome iron ore. There was one statement in the paper which caught his attention, and which did not altogether tally with the results that he then obtained. M. Gautier stated in his paper that "the unreduced chrome ore makes a scaffolding and causes difficulties in the working, which shows clearly that chrome iron ore is not fluxed by silica, whether free or in the condition of silicates." In the experiments that he (Professor Huntington) had made he aimed at getting the oxide of iron to combine with silica, and the oxide of chromium with soda, so as to get the whole mass into a state of fusion. He did this on the same lines as some other work which he had found successful. The result of those experiments was, that the oxide of chromium remained combined with the oxide of iron, and the soda combined with the silica, until some oxidising agent was introduced, when the chromic acid combined with the soda, and the oxide of iron with the silica. There was no difficulty whatever in getting complete fusion of the mass, whether an oxidising agent were used or not. That showed at once that, at any rate, the statement in the paper wanted limiting. The inference was not correct that the scaffolding was due to the fact that chrome iron ore could not be acted on by silicates. It was simply in this case a question of temperature. Given sufficient temperature and the silicates would flux the chrome iron. In the absence of sufficient temperature the chrome iron would remain refractory. He would say, as regards lime, that very much the same effect was obtained, so that the statement that potash and soda alone could smelt the chrome iron ore also wanted slightly modifying. That brought him to the paragraph where it was stated that "in general metallurgy, where no alkalies in notable quantities are present, chrome iron is a refractory material, of a specially neutral character, since neither acids nor bases act upon it." Now, it was one of the methods of extracting chromium from its ore to use lime to get out the chromium as chromate of lime, therefore the lime had the same attitude to chromic acid as soda or potash. It appeared to him that the reason that chrome iron ore was not very readily attacked in a furnace lining by lime was this, that in the extraction of chromium from chrome iron ore it was an absolute necessity that oxygen should be supplied to the oxide of chromium to convert it into chromic acid. In the manufacturing process it was conveyed either by using nitre or by exposing the chrome iron ore to the action of the oxygen of the air in the furnace. Now, in the case of the furnace lining used for iron and steel work there was no oxidising material in the slag which would communicate oxygen to the oxide of chromium, and air had not ready access to it. He thought that probably the durability of the lining was due, at any rate to some extent, to that fact.*

---

* Professor Huntington has furnished the following supplementary notes taken from his laboratory book:—

	I.	II.
Cr_2O_3	53·0	46·485
FeO	27·1	28·737
Al_2O_3	10·6	3·942
MgO	9·3	16·642
SiO_2	...	5·000
	100·0	100·806

I. Mean of twelve published analyses of chrome iron ore. II. Analysis of the ore used. It was from Hungary.

The theoretical proportions for II. would be, for 100 ore, 65·1 carbonate of soda,

M. **Gautier** said he had brought a sample of the lining employed for the use of the chromium iron ore. It was made with limestone and dust of chrome iron, and it was very hard. It could scratch glass. He was very glad to know that Mr. Richards had tried the use of lumps of chrome iron ore in the basic process; but if he understood rightly, it was used in lumps in the walls of the converter.

Mr. **Richards** said it was used in its natural state, in blocks.

22·3 sand, 14·1 oxygen. Five-sixths of the oxygen in nitre is available for oxidising purposes, therefore 35·5 nitre required to supply 14·1 oxygen.

The following are some of the mixtures tried:—

1. Ore = 600, soda ash = 1200, sand = 240. Heated to bright redness for one and a half hour. Fused, and was poured into mould. Consisted of uniformly glassy slag of a dark olive green.

2. Ore = 600, soda ash = 1800, sand = 240. Heated for one hour; became uniformly very liquid.

3. Ore = 600, carbonate of soda = 1162, sand = 138. Kept at a high temperature for one hour and a half; became liquid. Consisted of a brown slag, containing, however, particles of ore. The ore in this experiment had been put through a sieve with 80 holes to linear inch.

Nos. 1 and 2 had been through 60 sieve.

4. A similar mixture to 3; heated for three hours. Result the same, except slag more uniform.

On powdering the product of the above four experiments and leaching them with water, only an extremely small amount of chromate of potassium was extracted.

The addition of a silicate (sand and soda) had fluxed the chrome iron ore.

In the following experiments oxygen was supplied by means of nitre:—

5. Ore = 600, carbonate of soda = 1800, sand = 360, nitre = 251·4. Heated for one hour and a half; became very liquid. A good deal of chromate, which floated on the top of the slag, was poured off, and found to have a weight = 150 parts of the mixture. The contents of the crucible were allowed to cool slowly; a little more chromate rose to the top. The slag was brown, with lines of green in it. On leaching a large amount of chromium went into solution.

6. Using a comparatively small excess of soda and potash. Ore = 600, carbonate of soda = 313, sand = 22·3, nitre = 243·6. Heated strongly for one hour and three-quarters; became very liquid on the top, but remained rather pasty at the bottom. A good deal of chromate had formed.

The addition of oxygen (by means of nitre) in Nos. 5 *and* 6 *had caused a complete change in the attitude of the constituents of the mixture to one another, and had also rendered the mixture more fusible.*

In the following experiments the rationale of the fluxing of chrome iron ore is further exemplified:—

7. Ore = 600, chloride of calcium = 432·5, sand = 22·3, nitrate of lime = 86·4. In the furnace for two hours at high temperature. Just fused, but would not pour. Consisted of very hard black glassy slag, with an earthy separation on the top, which was of a faint yellow colour. The slag, on being crushed and leached, yielded only a very small amount of chromium.

8. The same as 7, with the exception that the quantity of sand was readjusted, 41·5 parts being used. This mixture fused easily in an hour.

9. Ore = 600, sand = 31, chloride of calcium = 484·56. This mixture was heated in a muffle for three hours, but did not fuse. It remained as a brown mass slightly stuck together. It was ground up, placed in a crucible, and heated strongly in a furnace for two hours. It just became fused, forming a very hard slag.

The furnace used in all the above experiments was an ordinary assay furnace, burning coke, and worked with a chimney draught.

M. **Gautier** said it would then be like masonry.

Mr. **Richards** said it would; it was like walls made into a brick, but in its natural state. They had tried the ore pounded up and mixed with tar, making a nice brick; but the strong action of 25 lbs. in the Bessemer converter soon settled it.

M. **Gautier** said it was a question of burning.

Mr. **Richards** said it would not last two operations.

M. **Gautier** said he had tried first to use a mixture of tar with chrome iron ore in dust, and had found something which looked very solid, but which was very easy to burn, because when it was submitted to the heat it changed the tar into carbon, and, the carbon burning, all was crumbled to pieces.

Mr. **Richards** said it became disintegrated.

M. **Gautier** said it did. With that kind of hearth made of lumps of chrome iron ore and hard mortar, which they had at hand, it would last more than one year. In the works mentioned they had some furnaces whose hearths were made more than a year ago. He could not say the same for the vaults. Generally in France, where they were in the habit of saving all they could in coal, they were very much inclined to have low vaults, which were often cut by the flames, and they could not endure more than four months. As to the thickness of this lining for the hearth, it was only from eight to ten inches; but it would be enough if they had, as in France, iron frames and plates under. Eight or ten inches was enough, because, when there was an open iron framing, the hearth was cooled by the circulation of air. Now, with regard to this hearth and chrome iron ore, it was generally found in practice that there was no wear and tear, or a very slight amount. There were often some holes, the largest being perhaps about the size of a fist. They judged of it by the eye, put a piece of chrome iron ore about the same size in the hole with a kind of tool, made the part flat, and spread some limestone dust. They then subjected it to the heat of the furnace, and it became very solid. When there were some crackings in the hearth, which often arose, they only spread carbonate of lime over them, and the combination with the chrome iron ore was enough to stick and shut the small holes. Practically they employed about 50 lbs. or 60 lbs. of a mixture of chrome iron ore in dust and tar to stop the casting-hole. They did not at all fear the combustion by the air, because it was cooled on one side by the air, and on the other side it was covered by the bath of metal. They had tried to make bricks like those described by Mr. Riley, but they had found generally, when bricks and tar were subjected to heat, that they were easily burnt. They preferred to use the lumps with the mortar as cement; but, as Mr. Richards had explained, they found that it was not always easy to get good and solid lumps. With regard to the expense of the stopping with this mixture, to about £4 a ton of common chrome iron ore they spent about 6d. per ton of steel for the stopping of the casting-hole.

Mr. Richards asked if that was for general repairs.

M. Gautier said it was, because they used only limestone for the crackings. Professor Huntington was right in explaining the scaffolding in the manufacture of the *ferrochrome* by the want of oxidation and the deficiency of heat. Of course, the chemical action of lime on chromium iron ore was a question of temperature and of the oxidising action of the air, but in practice, and with a small percentage of lime in presence of chromium, a kind of cement was formed, which could not be smelted, however high the oxidising action and the temperature.

THE CONSTITUENTS OF CAST IRON.

By THOMAS TURNER, Assoc. R.S.M., F.C.S., Demonstrator of Chemistry, Mason College, Birmingham.

In the presidential address delivered by Dr. Percy to this Institute in 1885, the following remarks occur:—"It is not many years since we had to grope about to discover an analysis of iron ore or of pig iron, whereas now we are actually overwhelmed with such analyses. We are deluged with percentages of carbon, graphitic or combined, of silicon and manganese, of sulphur and phosphorus. We are bewildered by this vast accumulation of material, like the traveller in the mazes of a primeval American forest. What is now wanted is the man to reduce it to law and order, to evolve from it principles for our sure guidance" (p. 33). All who are acquainted with the various branches of iron analysis must feel how true the foregoing remarks are in the present state of our knowledge. For though chemical analyses abound in the various text-books and journals connected with the manufacture of iron and steel, we are still in many cases unable from the chemical analysis to predict with certainty the mechanical properties of a given specimen. It is true that by a knowledge of the composition of a particular sample of pig iron we may predict with considerable accuracy its suitability or otherwise for the various processes of steel-making, or for use in the forge. A very good or a very bad sample of steel may be also very generally recognised by analysis. But there is a large intermediate class of steels in which chemical analysis fails to indicate the true mechanical value, while very divergent opinions are expressed on the subject of the composition of cast iron most suitable for definite applications. It is probable that these difficulties are by no means dependent upon imperfections in methods of analysis, or any uncertainty in analysis as an index of mechanical value; but in many cases they arise from our own inability to rightly interpret the meaning of the analyses themselves. And, in the case of cast metal at least, our knowledge cannot be considered complete until we are able to correctly estimate the mechanical value of any given specimen of which the chemical analysis is known; and conversely, when any given mechanical properties are desired we should be able to say at once what would be the most suitable composition for the material.

The present paper is an attempt in some measure to systematise our knowledge of the constituents generally present in cast iron, so as to attain the two objects just mentioned. It is not to be expected that these objects can be completely realised at present, and my paper is more suggestive than dogmatic in a number of the points to which it refers. The whole subject is, as Dr. Percy observes, intricate and complex, and much systematic work yet remains to be done before the real influence of the various constituents can be considered as fully determined.

There is doubtless a great deal of knowledge of the effect of composition on the properties of cast iron which has been obtained by manufacturers as a result of long experience, and which is hidden in the iron works and foundries of this country. But in metallurgical books the information is of a very meagre description, and probably a considerable number of experienced ironfounders rely more on their own conclusions, based on the results of long practice, than upon any well-established chemical principles.

The elements which most commonly occur in cast iron are carbon, manganese, phosphorus, silicon, and sulphur, all of which are invariably present in greater or less proportion, and the influence of each we shall consider in detail. Besides these constant constituents there are others, such as arsenic, copper, and titanium, which occur less often. In older analyses, too, it is not uncommon to find the occurrence of aluminium, sodium, potassium, magnesium, and calcium; in some cases several per cent. of these constituents being returned. Doubtless many such statements were made upon an insufficient foundation, for at present we seldom hear of the occurrence of these elements. But it is probable that several of them at least would be found in small quantity perhaps more often than is generally supposed, if sought for with sufficient care. For even if they do not exist in cast iron in any other form, aluminium, magnesium, and calcium can be recognised in the small amount of intermingled slag which can be separated from this variety of metal. We cannot, however, at this time refer to any elements other than those which I have called the "constant constituents" of cast iron.

In connection with this subject there have been two opposite opinions advanced by different authorities, each of which found expression at the meeting of this Institute, held at Glasgow last autumn. On the one hand, it is suggested that probably the best mechanical properties would be obtained in a cast iron which contained, if possible, nothing but carbon and iron, all other elements being regarded as impurities. On the other hand, it is said that possibly very considerable quantities of other elements might be added, even upwards of ten per cent., without rendering the metal unfitted for the founder's use. It might be, if we could obtain chemically pure iron, and add to it only absolutely pure carbon, that the first suggestion would prove correct, and possibly, if the various constituents could be added in just such proportion as to neutralise each other's ill effects, as under some circumstances they are capable of doing, then the second suggestion might likewise prove true. But in the following pages I hope to show that practically neither of these views is correct. As a matter of fact we cannot manufacture pure iron, and we cannot neutralise the ill effects of large proportions of foreign substances. But what we can do is to produce a cast iron of tolerable purity, from which, by variations in the proportions of the constant constituents, we may prepare a metal of any desired character.

CARBON.

Carbon is the most important constituent of cast iron, and the one which appears to impart its characteristic properties. On account of the remarkable differences produced by variations in the proportions of combined carbon and graphite, which are even greater than those produced by variations in certain different elements, we shall consider total, combined, and graphitic carbon separately.

1. *Total Carbon.*—It is pretty commonly accepted that the border line between steel and cast iron is reached with about 1·5 per

cent. of carbon. Although some analyses, published upwards of thirty years ago, return upwards of 6 per cent. of carbon in a cast iron, probably all will agree with Mr. Snelus, who stated sixteen years since, that in several hundred analyses of all brands of iron, he had never in a single case found the carbon to reach 5 per cent.;* and this may be regarded as the maximum value. These numbers give a range of 3·5 per cent., but practically such large variations are not often observed. It is seldom that the amount of carbon exceeds 4 per cent. except when much manganese is present, as in spiegeleisen; and it is not often that less than 2·5 per cent. of carbon is found in cast iron, except when the proportion of silicon is unusually high, as in silicon pig, which with 10 per cent. of silicon generally contains under 2 per cent. of carbon. For the more ordinary irons the amount of carbon may be said to vary only from about 3 to 3·8 per cent., and about this proportion is generally preferred for foundry purposes, a smaller amount being considered objectionable.

It would, however, be incorrect to suppose that iron containing only 2 per cent. of carbon is of necessity deficient in any of the important characters of the very best cast iron. On the contrary, I have shown that an excellent foundry iron may be produced with only 2 per cent. of carbon; this gave remarkably good castings, was very soft to the tool, and possessed a tensile strength of nearly 16 tons per square inch.† The objection to low carbon cast iron is probably connected with the fact that its production is generally due to some irregularity in the working of the blast furnace, and the iron is apt to be somewhat irregular in its character also. Hence, when a uniform product is desired, low carbon cast irons, made in the blast furnace, are undesirable, but when prepared by suitable mixing they often possess unusual strength.

Combined Carbon.—The influence of carbon in combination with iron is well known. When present to the extent of several per cent. it renders the metal harder than the best tool steel, and it is then brittle and deficient in tenacity. With the separation of graphitic carbon, however, the mass becomes honeycombed with a multitude of small particles, each of which is softer and weaker than the metal surrounding it; and as a consequence, highly graphitic iron is soft and weak. By a combination of the two extremes in due proportion we obtain a metal suited to the purpose we have in view. Or in the words of Schiller, himself an experienced founder, we observe—

---

* *Journal*, i. p. 33.

† *Jour. Chem. Soc.* 1885, p. 580.

> "Ob das Spröde mit dem Weichen,
> Sich vereint zum gutem Zeichen."

It is important to notice the manner in which this combination is produced. We can only affect the relative proportion of graphitic to combined carbon in one of two ways. In the first place, by a difference in the methods of cooling after fusion the amount of combined carbon can be, to a small extent, increased or diminished at will. But by far the most important effect is caused by variations in the proportion of other elements present. Thus an increase of manganese, sulphur, and probably phosphorus, necessarily produces an increase in the proportion of combined carbon, while the addition of silicon produces an exactly contrary effect. And hence in the proportion of other elements, when rightly interpreted, we have an indication of the relative amounts of graphitic and combined carbon.

This fact has hitherto been far too often overlooked by those who make mixtures of various kinds of iron. We frequently hear of iron as of a hard or soft "nature" as the case may be, and it is forgotten that this "nature" is not unalterable. A sample of iron can be either hardened or softened at will, when its chemical analysis is known, by slight alterations in the proportion of its constituents. And these alterations can be made with no extra expense to the founder, if he proceeds upon certain fixed and definite principles. Of these I have recently given a partial account,* but shall endeavour to render this account more complete and well defined in these pages.

Unfortunately hitherto we have had but little accurate data as to the most suitable proportion of combined carbon for iron of definite mechanical properties. Single analyses dispersed throughout a number of books are of little value for this purpose; what is wanted is a series of experiments, either like those conducted at Woolwich in 1856–58, in which a large number of specimens were examined both chemically and mechanically, and the results tabulated in a form suitable for comparison; or, on the other hand, a series in which one constituent varies while all others remain as nearly as possible constant. It is to be regretted that in the Woolwich report there are but few returns of combined carbon, and hence my conclusions are based chiefly upon my own observations, supplemented by the important results of Mr. Charles Wood.* My experiments were principally conducted upon bars of 1-inch diameter, and weighing only about 7 pounds, and as a consequence the amount of combined carbon in the intermediate bars, which were produced by mixing silicon pig with white iron, is somewhat higher than that observed by Mr. Wood, who used a larger amount of material. This difference is due to the more rapid solidification of the smaller quantity of metal, and as a consequence also, somewhat greater variations are observed, caused by slight differences in temperature or the state of the mould. Hence Mr. Wood's numbers for combined carbon are probably nearer than my own for practical purposes, though both show the same general character.

---

* *Jour. Soc. of Chem. Indust.* 1886.

The lowest combined carbon is met with in cast iron, which contains from 4 to 7 per cent. of silicon, the quantity varying from a trace to 0·2 per cent., according to composition and size of casting. This class of metal is weak and rather hard, as the most suitable amount of silicon has been exceeded. The softest cast iron differs from that just mentioned usually by containing a few hundredths per cent. more combined carbon, the difference in character being due to alteration in other constituents, often silicon. Thus Mr. Stead's analysis shows (p. 467) the combined carbon of

Silicon pig	0·10 per cent.
Softest mixture	0·14 „ „

or a difference of only 0·04 per cent. Other analyses show even a smaller difference; but it appears that the softest metal always contains a trace more combined carbon than 5 per cent. silicon iron. The maximum general strength is obtained with not less than 0·4 per cent. of combined carbon, the metal being sufficiently soft to work with the tool, the tensile and crushing strengths being both tolerably high. With more combined carbon the metal becomes harder, the crushing strength increases, while the tensile strength diminishes, and a metal suitable for rolls is obtained; this class of iron not unfrequently contains upwards of 1 per cent. of combined carbon. It is interesting to notice also that though silicious iron with about 5 per cent. of silicon usually has little more than a trace of combined carbon, this amount again *increases* with a higher proportion of silicon; hence large amounts of silicon appear to have an exactly contrary effect on combined carbon to that of smaller quantities. Thus, in my own observations it was noticed that

---

* *Journal* 1885, ii. p. 464.

Silicious iron, 3·92 per cent., contained 0·20 combined carbon.
" " 4·74 " " " 0·37 " "
" " 7·33 " " " 0·38 " "
Silicious pig, 9·80 " " " 0·69 " "

And in several other specimens of silicon pig, containing about 10 per cent. of silicon, the amount of combined carbon has been found to be about 0·70 per cent.

On arranging the different qualities of iron in order of combined carbon we have the following summary:—

	Combined Carbon.
Silicious iron, silicon 4 to 5 per cent. . .	trace to 0·2 per cent.
Softest cast iron	about 0·15 " "
Greatest general strength	about 0·5 " "
Silicon pig, silicon 10 per cent. . . .	about 0·7 " "
Greatest crushing strength	upwards of 1 " "

The term "general strength" is applied to a cast iron in which a considerable crushing strength is accompanied by a high tensile strength. In this case the transverse and torsional strength will probably also be high. As we have seen, the amount of combined carbon will vary according to the properties which are desired, either crushing or tensile strength being made to increase or decrease at will. And it is to be remembered that any required proportion of combined carbon may be obtained by altering the amount of silicon on the one hand, or of manganese and sulphur on the other.

Graphitic Carbon.—The amount of graphitic carbon will obviously depend upon the percentage of total carbon, and the proportion of this which is in the combined form. We have therefore already partly considered the most suitable proportion of graphite when speaking of combined carbon, since this value can be obtained by subtraction when the total carbon is known. In considering the most suitable amount of graphite, it will be necessary to assume a certain quantity of total carbon. The average for British cast iron is about 3·4 per cent., and this may be taken as a standard. Now since variations in the amount of total carbon have less influence on the properties of the metal than equal variations in the proportion of combined carbon, it follows that small variations in the amount of graphite are less important than equal variations in the amount of combined carbon. To illustrate my meaning, three specimens of iron having the following composition would not differ very materially in strength and hardness:—

No. 1.	Graphite,	2·7,	combined,	0·3
No. 2.	„	2·9,	„	0·3
No. 3.	„	3·1,	„	0·3

because a small increase in graphite, while combined carbon remained constant, would not very much affect the ratio of the two forms of carbon to each other. But on the other hand, if a similar alteration of 0·4 per cent. had taken place in combined carbon while the graphite had remained constant, the ratio would have been considerably altered, and the properties of the metal would be very different.

In the report "Cast Iron Experiments, 1858," p. 154, there are given the analyses and mechanical tests of fifty-three samples of cast iron. Of these, fourteen contained upwards of 3·1 per cent. of graphite, and it is shown that only two out of the fourteen were of more than average quality. The six specimens possessing the highest tensile strength contained on an average 2·73 per cent. of graphite, while the average graphite in the six specimens with greatest crushing strength was 2·59 per cent. It should be mentioned, however, that in obtaining this last average specimens common to both classes have been omitted, as also two other specimens which contained upwards of 1 per cent. of phosphorus.

These numbers will obviously depend to a considerable extent on the amount of total carbon present, but probably in the majority of cases the following values will be found best:—

For crushing strength under	2·6 per cent.
„ general strength about	2·8 „
„ strength and softness about	3·0 „
„ Softness over	3·1 „

These numbers are only correct, however, when the total carbon is about 3·4 per cent., and some remarks on the effect of smaller amounts of graphite will be made at a later stage in this paper.

SILICON.

In order of importance silicon ranks next to carbon as a constituent of cast iron. It is always present in cast iron, and the variations in the proportions in which it occurs are very considerable. Thus in iron employed in the foundry we have a maximum range of about 4 per cent. in silicon, while for special purposes iron is manufactured which contains upwards of 10 per cent. Its influence on the character of the metal is very important, though complex, depending upon three separate effects.

1. That of silicon upon iron itself.
2. On the condition of the carbon present.
3. Its effect on the other elements present.

The last of these is at present very little understood, and is probably of least importance; practically, we have to do with the resultant of the other two effects. And for many purposes the proportion of combined carbon will serve as an index to this resultant.

For the majority of the applications of cast iron silicon is no more entitled to be considered an impurity than carbon. Either an excess or a deficiency of total carbon is justly regarded as undesirable; and we have seen that an alteration in the amount of combined carbon entirely alters the suitability of cast iron for a particular application. It is precisely the same in the case of silicon; either too much or too little is undesirable. In some cases an addition of silicon materially improves the mechanical properties of the metal, while in other cases these properties are just as much improved by reducing the amount.

During the last three years I have been engaged upon some experiments intended to determine the influence of silicon on the properties of cast iron. The most important results have already been published in the *Journal of the Chemical Society*, but I shall venture here to refer briefly to the experiments and to give a short summary of the conclusions.

Condition of Silicon.—It was formerly pretty generally considered that silicon, like carbon, existed in cast iron in two distinct forms, one crystalline and the other corresponding to "combined" carbon. If this were the case it is obvious that it would be necessary to estimate both the graphitic and combined silicon separately before any trustworthy opinion could be formed as to its influence on the properties of the metal. We are indebted to Mr. Snelus for experiments, recorded in the first volume of this journal, which show that graphitic silicon is an uncommon constituent of cast iron, even if it ever occurs. Later observations were made by Morton, Tilden, and others, with similar result; and, in conjunction with Mr. A. E. Jordan, I have recently conducted some investigations on the same subject.* We were unable to find crystallised silicon in the residue left on treatment of silicious iron with an acid, nor could it be separated from cast iron by means of a magnet. We were equally unsuccessful with two specimens of graphitic matter separated from cast iron. And in the discussion which followed the reading of this paper † Sir F. Abel stated that graphitic silicon had not been met with in the analyses, known to be so numerous and careful, which have been conducted at Woolwich Arsenal. Hence it may be considered settled, that in the vast majority of cases at least, silicon occurs in only one form; and that, apart from the small quantity of slag usually present, we only require to know the total silicon in order to determine its effect on the product.

Influence of Silicon.—Much diversity of opinion has been expressed on the question of the effect produced by silicon when present in cast iron. Thus Professor Calvert said that "the presence of sulphur, phosphorus, arsenic, or silicon, is always injurious;" ‡ while Mr. Gjers has stated that "silicious or glazed pigs were always bad and unreliable, no matter what they were mixed with." § On the other hand, some writers have contended that in the more usual proportions silicon is not injurious; || and Mr. Snelus, writing fifteen years ago, said, "It is generally supposed that the absorption of much silicon tends to set free carbon in the graphitic state." ¶ This would obviously, in some cases, be beneficial.

In my own experiments cast iron of more than usual purity was specially prepared by heating South Staffordshire wrought iron

---

* *Journal Chem. Soc.*, 1886, p. 215.

† *Abstracts of Proceedings*, p. 156.

‡ *Institute of Civil Engineers*, 1852-3, p. 354.

§ *Journal*, 1885, ii. p. 474.

|| *Watts's Dict.*, iii. 334.

¶ *Journal*, i. p. 36.

in crucibles with charcoal. The product was then mixed with various amounts of silicon pig, and the resulting metal examined chemically and mechanically.

The materials employed had the following composition:—

Description.	Total Carbon.	Graphite.	Si.	P.	Mn.	S.
Original cast iron .	1·98	0·38	0·19	0·32	0·14	0·05
Silicon pig . . .	1·81	1·12	9·80	0·21	1·95	0·04

The total carbon was purposely kept as nearly as possible constant at 2 per cent., so as to obviate any uncertainty due to variations in that element. The only element other than silicon which varied to any considerable extent was manganese; but in this case the alterations were rather less than one-fifth of the variations in silicon, and would not appear to have introduced an appreciable error.

In Table A the results of my experiments are collected together for the first time. In addition to what has been previously published, there is added a specimen containing 1·4 per cent of silicon, as that appeared from my earlier experiments to be of considerable interest. There is also given the calculated transverse strength, which is of importance in connecting together tensile and crushing strength. The results obtained are represented graphically in Figs. I., II., and III. The tensile and crushing tests were performed by Professor A. B. W. Kennedy, of University College, while I am indebted to Mr. J. P. Walton for assistance in the analytical part of the work.

Density.—An examination of the relative density of the specimens shows that, when examined in the form of *turnings*, the density of cast iron is decreased with tolerable uniformity by the addition of silicon. It also affords strong confirmation of the statement of the American Commissioners on Ordnance, 1856, that "the tenacity increases quite uniformly with the density until the latter ascends to some given point, after which an increased density is accompanied by a diminished tenacity." In these experiments it will be seen that the maximum tenacity is reached with a density of 7·35 in the turnings, or 7·518 in mass, the temperature being 20° C. The difference in these two values is due to the

TABLE A.—EFFECT OF SILICON ON THE PROPERTIES OF CAST IRON.

Silicon, per cent. (calculated).	Relative Density at 20° C. (Water at 20° = 1.)		Relative Hardness.	Tensile Strength = per Square Inch.		Modulus of Elasticity.	Crushing Strength per Square Inch.		Calculated Transverse Strength. Bars 1 foot long, 1 inch square, loaded in the centre.		CHEMICAL ANALYSIS.						
	Cylinders.	Turnings.									Tota Carbon.	Graphite.	Combined Carbon.	Silicon.	Phosphorus.	Manganese.	Sulphur.
				Lbs.	Tons.		Lbs.	Tons.	Lbs.	Tons.							
0	7·560	7·719	72	22,720	10·14	25,790,000	168,700	75·30	2,702	1·206	1·98	0·38	1·60	0·19	0·32	0·14	0·05
0·5	7·510*	7·670	52	27,580	12·31	28,670,000	204,800	91·42	3,280	1·464	2·00	0·10	1·90	0·45	0·33	0·21	0·05
1	7·641	7·630	42	28,490	12·72	31,180,000	207,300	92·54	3,370	1·504	2·09	0·24	1·85	0·96	0·33	0·26	0·04
1·4	7·555	7·473	...	31,440	14·04	23,500,000	183,900	82·08	3,498	1·561	2·21	0·50	1·71	1·37	0·30	...	0·05
2	7·518	7·350	22	35,180	15·70	23,560,000	137,300	61·29	3,446	1·538	2·18	1·62	0·56	1·96	0·28	0·60	0·03
2·5	7·422	7·388	22	32,760	14·62	25,450,000	172,900†	77·18†	3,534†	1·577†	1·87	1·19	0·68	2·51	0·26	0·75	0·05
3	7·258	7·279	22	27,390	12·23	21,150,000	128,700	57·45	2,850	1·272	2·23	1·43	0·80	2·96	0·34	0·70	0·04
4	7·183	7·218	27	25,280	11·28	15,640,000	106,900	47·74	2,543	1·135	2·01	1·81	0·20	3·92	0·33	0·84	0·03
5	7·167	7·170	32	22,750	10·16	18,720,000	103,400	46·16	2,342	1·046	2·03	1·66	0·37	4·74	0·30	0·95	0·05
7·5	7·128	7·138	42	11,950	5·34	14,750,000	111,000	49·55	1,505	0·672	1·86	1·48	0·38	7·33	0·29	1·36	0·03
10	6·978	6·924	57	10,630	4·75	13,930,000	76,380	34·10	1,252	0·559	1·81	1·12	0·69	9·80	0·21	1·95	0·04

* This number is rather low, as the specimen afterwards proved to be somewhat faulty.

† The value in this case is probably exceptionally high; a crushing strength of about 60 tons might be anticipated from its position in the series.

effect produced on the density of the metal by the force exerted during turning. On the other hand, it will be noticed that the density in *mass* affords an excellent index to the crushing strength, which varies quite uniformly with the density, the maximum being in each case with 1 per cent. of silicon. This observation agrees with the result of the Woolwich experiments of 1858, in which the specimen with maximum density also possessed the greatest crushing strength; and a close connection was shown to hold good between these two characters in a large number of cases.

Hardness.—The hardness was determined by the weight in grams necessary to produce a scratch with a cutting diamond when drawn over a smooth surface of the metal. It is therefore entirely relative, but could be made "absolute" by comparison, in a similar manner, with minerals of known hardness. As thus determined, it agreed remarkably well with the experience of a skilled workman who turned the specimens, and is doubtless a far preferable mode of expressing hardness to that of "hard," "very hard," &c., of the practical man. The latter method is chiefly of value to the man who makes the observation, but is of little importance as a guide to others.

There have been hitherto but few recorded determinations of the hardness of cast iron. The American experimenters adopted a method which was at once troublesome and open to some objection. A tool in the form of a pyramid was pressed against the metal to be tested with a weight of 10,000 lbs.; the size of the indentation was measured and the cubic content calculated. When recalculated by Pole * they show a range of from 2·55 to 10·1, or about 1 : 3·9; while my own experiments show a maximum variation of from 22 to 72, or nearly 1 : 3·3, an agreement which is quite as good as might be anticipated.

Tensile strength.—The tensile strength will be seen to vary with remarkable uniformity, attaining a maximum of 15·7 tons, with two per cent. of silicon. This is an unusually high value for cast iron, though it has been exceeded by the American experimenters with 20·5 tons, and very nearly approached in the Woolwich experiments of 1858 with 15·3 tons. I believe that, starting with good materials, by careful mixing, a tensile strength of 15 tons per square inch, as measured by bars one inch in diameter, could be regularly assured. On this subject I have entered into some detail in a recent paper.*

---

* *Iron Construction*, p. 100.

In modulus of elasticity a maximum value is obtained with 1 per cent. of silicon. In the first seven members of the series exceptionally high values are obtained, which are probably connected with the low percentage of total carbon; but to this I shall return at a later stage.

Crushing strength.—The crushing strength also shows a very considerable uniformity, the only exception being the 2·5 per cent. specimen, which is probably rather too high, owing to the small amount of graphitic carbon. The maximum value of 92·54 tons was obtained with 1 per cent. of silicon. This value, though greater than is usual with cast iron, has been exceeded by Sir W. Fairbairn, who in 1853 recorded a crushing strength of nearly 96 tons.

Transverse strength.—The numbers given for transverse strength are not the result of experiment, but are calculated from the observed tensile and crushing strength by a formula given by Box ("Strength of Materials," p. 496), and which is proved to give results which accord fairly well with direct observations.† The values are for a bar one foot long by one inch square. These numbers have been calculated for the purpose of combining together, if possible, in a practical manner the observed crushing and transverse strengths. If they should be objected to by engineers on the score of our imperfect knowledge of the connections between transverse strength with tensile and crushing strength or modulus of elasticity, I have only to urge that such methods of calculation are probably the best which we at present possess, and that for the purposes I have in view they are doubtless quite sufficiently exact. It should be mentioned, too, that I have applied the formula used here in a number of cases, and found the calculated results to agree very fairly with those found by experiment. The

---

* *Journal Soc. Chem. Indust.*, 1886.

† The formula is as follows:—

$$W=\left(\frac{\sqrt{c}}{\sqrt{c}+\sqrt{T}}\times d\right)^2\times b\times T\div(L\times 4{\cdot}5).$$

results of previous direct observations, when calculated to bars of one foot long by one inch square, are as follows:—

	lbs.
Cast iron experiments 1858, mean of 53 samples	1479 [*]
Hodgkinson & Fairbairn, mean of 221 experiments	2063 [†]
Cast iron experiments 1858, maximum of 564 specimens . .	2358 [*]
Hodgkinson & Fairbairn, maximum	2632 [†]
Fairbairn, remelting of cast iron, 1853, maximum . . .	3114 [‡]
Stirling's toughened cast iron, mean	3299 [§]

My own calculated values vary from 1252 to about 3500 lbs. This latter number forcibly illustrates what appears to be a somewhat remarkable point in these experiments, namely, the combination of a high tensile strength with a great power of resistance to compression. Thus, while in the Woolwich experiments a tensile strength of over 15 tons was observed, and the unusually high average of 10·4 tons obtained, these values were accompanied by an exceptionally low crushing strength, the maximum only reaching 62·5 tons. On the other hand, while Fairbairn records so high a crushing strength as 95·9 tons, his maximum tensile strength was only 12·5 tons, and these two values were not obtained in the same specimen. In my own experiments, however, the following values were obtained:—

Silicon.	Tensile Strength.	Crushing Strength.
0·5	12·31	91·42
1	12·72	92·54
1·4	14·04	82·08
2	15·70	61·29
2·5	14·62	77·18

No such combination of crushing and tensile strength as is exhibited in either of the above specimens is to be found recorded by any of the investigators to whom I have previously referred. An exception to this statement must be made in the case of "Stirling's Toughened Cast Iron," of which a maximum transverse strength of 3906 lbs. is recorded.[‖] This was prepared by melting soft cast iron with wrought iron scrap in suitable quantity, usually under

---

[*] Report, 1856, p. 2.

[†] Box, p. 186.

[‡] B. A. Report, 1853, p. 87.

[§] Stirling, Inst. M. E., 1853, p. 22.

Box, p. 504.

33 per cent. The product, therefore, was low in silicon and total carbon, and possessed very high tensile and crushing strength. It should be mentioned that in my experiments the high crushing strength is not due to the shape of the test pieces employed. These were cylinders 3 inches long and 0·75 inch diameter, and this form would give results rather under than above the average.

It would be of interest to determine the exact characters of the iron which have produced the above results. Although the influence of silicon on the specimens is plainly marked, the whole of the good effect is not due to this cause alone. It appears to be due to the very superior quality of the original iron, combined with the effect of a certain proportion of silicon. It will be seen that the amount of manganese is but small, while the proportion of sulphur and phosphorus is very nearly constant, and is such as I shall recommend as most suitable for the production of strong cast iron when referring in detail to the influence of these two elements on the metal. It is also probable that the proportion of carbon which is present exerted a beneficial influence.

High crushing strength appears to be closely connected with low graphitic carbon; on the other hand, tensile strength diminishes when combined carbon is high. Hence to obtain combined crushing and tensile strength neither graphite nor combined carbon should be present in large quantity, though both are necessary. It is obvious that these conditions can be best realised when the proportion of total carbon is not unusually high, and an excess of carbon is as much to be avoided in this class of iron as an excess of silicon or any other ingredient.

From the brief summary of the more important results of these experiments, which has been now given, it will be evident that by variations in the amount of silicon a cast iron may be produced possessing any desired mechanical properties. Thus if a high crushing strength be required, it can be obtained by a low percentage of silicon; if a high tensile strength is wanted, the silicon should be somewhat higher; while for softness, smoothness of surface, and fluidity a still higher proportion is necessary. If, however, the amount be unduly increased the product is rendered quite unfit for many applications. In the production of chilled castings also the proportion of silicon is of great importance, since by the presence of a sufficient amount of this element chilling may be altogether prevented; on the other hand, if too little silicon is present white iron results.

If the numbers given in Table A be represented graphically by means of curves, it will be seen that the following values probably represent the proportions of silicon which should be present in order to produce cast iron of given mechanical properties.

Maximum hardness	under 0·80	per cent.
Crushing strength	about 0·80	,,
Modulus of elasticity	,, 1·00	,,
Density, in mass	,, 1·00	,,
Combined crushing and tensile Strength; transverse strength	,, 1·40	,,
Tensile strength	,, 1·80	,,
Softness and working qualities	,, 2·50	,,
Lowest combined carbon	under 5·00	,,

These values are liable, however, to be considerably modified by any large alterations in the proportions of other elements, especially manganese and sulphur, and, to a smaller extent, phosphorus, which act in such a manner as to neutralise the effect of a certain part of the silicon present. In practice, however, these alterations should introduce but little difficulty, as the amount of silicon can readily be altered to suit the varied circumstances. But though irons of this class can be considerably improved in many cases by suitable mixture, it must not be supposed that irons rich in manganese, phosphorus, or sulphur, will produce so good a product for many purposes as in the case of metal of better chemical quality.

In the discussion which followed the reading of Mr. Wood's paper at the last meeting of this Institute, several speakers, of very considerable practical experience, attributed the whole of the good effects produced in the experiments mentioned to the effect of silicon on the proportion of graphitic carbon. It should be pointed out, however, that such an argument is not founded upon observation, but upon supposition. It does not by any means follow because a large proportion of silicon renders the iron almost worthless for many purposes, that therefore a small proportion is injurious. Numerous cases could be cited in metallurgy where an excess of a constituent is injurious, while a suitable amount is beneficial or even necessary. As a case in point we have combined carbon in cast iron; undoubtedly too much of this renders the metal unfitted for many important applications, and yet we have seen that too little combined carbon is not to be recommended, but that it should be in proportion suited to the purpose in view.

Among other arguments which might be brought forward in connection with this point, the following are worthy of mention:—

1. If the curve of graphitic or combined carbon be drawn in a manner similar to the curves of hardness, tensile strength, &c., given in Figs. II. and III., it will be found that the curve so obtained does not coincide with any of those just mentioned.

In general form the combined carbon curve agrees most nearly with the curve of hardness, but its minimum point is at least 1 per cent. higher in silicon. In other words, if the result were due to the influence of silicon on the amount of combined carbon alone, then the minimum of combined carbon should be obtained with about 1·4 per cent. of silicon, or 2·5 per cent. at most, whereas in point of fact it is found with nearly 5 per cent. of silicon.

2. On examining Table A, it will be seen that with a regular and progressive increase of silicon, the alteration in mechanical properties is equally regular and progressive; but the combined carbon does not undergo the same regular alteration. Thus in the first four specimens we find a perfectly regular alteration in properties, though the combined carbon is not diminished, as would be the case if the variations were due to this cause.

3. It is unreasonable to suppose that an element such as silicon could be present, often to the extent of several per cent. without exerting a direct and marked effect on the qualities of the material.

It is therefore a legitimate inference that the effect observed on varying the proportion of silicon is the resultant of two causes; first, the influence of this element on the iron itself; and, secondly, what may perhaps be of equal importance, its effect on the condition of the carbon present.

PHOSPHORUS.

Phosphorus is generally regarded as an altogether objectionable constituent in cast iron. Doubtless for many purposes this objection is well founded, but in the case of foundry iron it is at least very doubtful whether this wholesale condemnation can be sustained. In many instances persons have been too ready to jump to the conclusion that because phosphorus is objectionable in wrought iron and in steel, that therefore it must of necessity also be objectionable, in any and all proportions, in cast iron. What is badly wanted at the present moment is a series of experiments in which various proportions of phosphorus should be added to a specimen of cast iron in which all other constituents should be kept as nearly as possible constant; for I feel assured that it is only by such experiments that accurate and reliable information can be obtained.

In the meantime, however, it can be readily proved that, in many cases at least, a small amount of phosphorus in cast-iron does not exert any prejudicial influence. Thus in the report, "Cast-Iron Experiments, 1858," which gives most complete and trustworthy information on the constituents of cast iron, we have recorded analyses and mechanical tests of over fifty specimens of British cast iron. These include a number of examples of non-phosphoric, moderately and highly phosphoric irons; and it will be found that the six specimens which possessed the highest average quality were all moderately phosphoric irons, the proportion varying from a minimum of 0·19 to a maximum of 0·72 per cent.* These facts show conclusively that a small proportion of phosphorus is not injurious in cast iron.

In the paper to which I have just referred all the specimens mentioned in the report are classified according to the proportion of phosphorus, and arranged in order of silicon, to illustrate the influence of the latter element. If the various tables are examined and an average obtained from each, we find the following result:—

---

* Compare Turner, *Jour. Chem. Soc.*, 1886, p. 135, where fuller details of these specimens are given.

TABLE B.

Table in *Jour. Chem. Soc.*	Number of Specimens.	Phosphorus.	Mean Order of Quality.
K.	9	under 0·2	32·6
L.	14	0·2 to 0·4	20·5
M.	9	0·4 to 0·6	23·8
N.	8	0·6 to 1·0	23·5
O.	10	over 1·0	32·2

The "mean order of quality" is obtained from determinations of the density, tensile, transverse, torsional, and crushing strengths, the specimens being arranged in order of quality in each of these characters. The numbers just given show that specimens which contained under 0·2 or over 1 per cent. of phosphorus were of low average quality, while the best result was obtained with 0·2 to 0·4 per cent. It is true that in the first and last of these tables the amount of silicon varies considerably among the different specimens, but even when this has been allowed for there appears to be a perceptible effect due to a suitable proportion of phosphorus. From the analyses given in Table A. it will be seen that in my experiments, where exceptionally good results were obtained, the amount of phosphorus was about 0·3 per cent. This would appear, therefore, to be a very suitable proportion for strong iron.

These facts will help in some measure to explain the well-known good effect produced by certain mixtures of iron, since by this means the silicon and phosphorus are obtained in a proportion which is more or less suited for the purpose in view. It also explains why in many cases moderately phosphoric iron is preferred for use in the foundry. In fact irons may be classed, according to their content of phosphorus, as most suited for—

1. The Acid Bessemer (or similar) process.
2. Foundry iron.
3. The Basic Bessemer process.

Though in the cases previously given it would appear that deterioration did not become very marked until the proportion of phosphorus exceeded 1 per cent., still for some purposes it is preferable to have a smaller maximum proportion. This is especially the case when considerable power of resistance to impact is desired, since phosphorus renders cast iron brittle. I am informed that experiments with cast iron shot, conducted at Shoeburyness, have shown that when the proportion exceeds about 0·4 per cent. the shot flies to pieces on striking the target. Hence though a small proportion of phosphorus is beneficial, that amount will require to be proportioned according to the object which the founder has in view.

SULPHUR.

We are still in need of exact information as to the influence of sulphur in cast iron, especially in presence of varying quantities of other elements, especially silicon. It has been shown that the addition of much sulphur to cast iron causes the separation of a portion of the carbon present in a form closely resembling graphite,* though a careful examination will prove, that in many cases at least this graphitic matter is by no means pure carbon. A *small* quantity of sulphur is known to produce hard white iron, owing to an increase in the amount of combined carbon. It therefore acts, in small quantity, in a manner which is almost exactly opposite to that of silicon.

In connection with the influence of sulphur on cast iron the Woolwich experiments of 1858 are of but little assistance, since the highest sulphur recorded was only 0·13 per cent.; the specimen containing in addition 1·07 per cent. of phosphorus, and being too hard to turn. It appears also that in the majority of cases in these experiments when sulphur exceeded 0·1 per cent., increased hardness was observed. Until lately I attached considerable importance to the experiments of Sir W. Fairbairn, in 1853, with which determinations of sulphur were given in certain cases; but quite recently I have had occasion to believe that these determinations of sulphur are altogether untrustworthy.

But it has been shown by Sir Lowthian Bell, and others, that in white cast iron the amount of silicon is usually low, while the proportion of sulphur is generally rather over 0·3 per cent. In mottled iron sulphur is usually present to about 0·1 to 0·3 per cent. while in grey iron it seldom exceeds 0·15 per cent. It may be mentioned that a number of experiments of my own entirely confirm the above statements.

---

* Percy, *Iron and Steel*, p. 131, *et seq.*

It is known that it is very unusual to find any considerable proportion of sulphur in a highly silicious iron. In very exceptional cases such a combination is met with, and by suitable means a large proportion of sulphur may be introduced even into a 10 per cent. silicon pig. But as a result of some experiments, not yet completed, I am inclined to believe that practically sulphur and silicon are, at least to a considerable extent, mutually exclusive of each other in cast iron. Thus an addition of sulphur to a silicious iron causes the separation of graphitic matter containing silicon; while on the other hand the addition of silicon to an iron rich in sulphur causes the separation of graphitic matter rich in sulphur. In the blast furnace, in presence of slag, this separated material would be readily removed, and hence the effect of either sulphur or silicon predominates in the product as the case may be. These statements, if substantiated by further work, as I believe they will be, would help to explain the effect produced by variations in temperature of the blast furnace on the character of the iron.

It has been stated by a number of authorities, among whom may be mentioned Mushet, T. Thomson, Fairbairn, and Mallet, that in Sweden in certain works, a small quantity of pyrites is added to the furnace charge, in order to impart greater hardness for special purposes. Recently Dr. Percy has assured me of the correctness of this, so that it may be accepted as an indisputable fact; and the effect is said to be in some cases very beneficial. Unfortunately at present I have had little or no experience of Swedish iron, and so cannot say whether the same effect might not have been produced by other means less open to objection. But of this we may be tolerably certain, that in the vast majority of British irons such a course is by no means to be recommended. Among other objections to this practice the following may be mentioned:—

1. Sulphur acts in a manner which is almost exactly opposite to that of silicon, and is very powerful in this action. It is probable that one part of sulphur neutralises the effect of at least from five to ten parts of silicon. Hence very small alterations of

sulphur produce great changes in the product, and the addition of sulphur to iron much resembles playing with edged tools.

2. When the amount of sulphur is at all large, it is liable to be considerably altered during remelting; the character of the product is therefore liable to considerable variation.

It is quite a mistake to suppose that a high sulphur is necessary in order to produce a great crushing strength, for it will be remembered that in my own experiments a crushing strength of 92·5 tons was obtained, though the amount of sulphur never exceeded 0·05 per cent. Still I am not prepared to assert, on the other hand, that a small proportion of sulphur is actually injurious; indeed, that is rather unlikely, and it may even be beneficial. But the amount of sulphur which may with advantage be present in foundry iron is certainly very small. Probably the following values will be found tolerably correct:—

For soft foundry iron,	not to exceed 0·13	per cent.
„ hard or mottled iron,	about 0·2	„ „
„ white iron,	over 0·25	„ „

These numbers will obviously be modified to some extent by the amount of silicon present.

MANGANESE.

A series of direct experiments to determine the effect of manganese when present in cast iron would be of considerable interest. But in the absence of this we reason from the somewhat meagre array of facts which have been observed. Referring once more to the Report, "Cast Iron Experiments, 1858," if we arrange the fifty specimens there mentioned in three classes according to the percentage of manganese, we get the following result:—

No. of Specimens.	Manganese.	Mean order of Quality.
12	Under 0·2	31·8
23	0·2 to 0·75	23·3
15	Over 0·75	26·0

From this it would appear that the specimens containing 0·2 to 0·75 per cent. of manganese were at once the most numerous and the best. But it should be mentioned that in the specimens low in manganese the silicon is often rather high, and consequently causes some deterioration. Arguing from the known properties of spiegeleisen and the figures just given, we should not be safe in concluding more than that a considerable amount of manganese renders cast iron unfit for many applications, its effect in this direction becoming evident when the proportion approaches 1 per cent. On the other hand, from 0·2 to 0·75 per cent. appears to exercise no injurious effect in the majority of cases, and may even be beneficial; while so low a proportion as 0·2 per cent., or under, is of doubtful advantage.

We have now considered the most important constituents which are commonly present in cast iron, and the proportions of each which appear to be most suitable for the production of a cast iron of given mechanical properties. It may be of interest to briefly examine the composition of a few specimens of what may be considered exceptionally good cast iron, and to compare the observations obtained in practice, with the statements made in the earlier portions of this paper.

Referring once more to the Woolwich experiments, which furnish what is probably the most complete and accurate series of tests of cast iron which we possess, we examine what may be regarded as the exceptionally good irons mentioned in this report. It has been previously stated that the 53 specimens examined were arranged in order of quality in specific gravity, tensile, transverse, torsional, and crushing strengths. Now selecting from these the three characters which are commonly regarded as most important, we may examine the six best specimens in each series, namely, those arranged according to tensile, transverse, and crushing strength. But it will be found that there are four specimens which occur in each of the three sets of six selected irons; and these four specimens may therefore be regarded as the four best specimens in the whole series, when combined crushing, transverse, and tensile strength is taken as our standard of quality. These irons are given in Table C, and it will be seen that they are of high density, and possess in addition a high resistance to torsion. In the case of the only exception to this latter statement, No. 4, it may be mentioned that in this iron all the specimens used in the torsion experiments proved to be defective, and this probably explains the exceptionally low result obtained. Considering therefore the excellent characters of these irons, and the fact that in each case the working qualities are returned as being "good," these specimens may be regarded as typical examples of excellent foundry iron.

TABLE C.—TYPICAL FOUNDRY IRON.

No.	By whom Supplied.	Description.	Chemical Analysis.					Order of Quality.					Mean.	Working Qualities.
			Mn.	Si.	Graphite.	S.	P.	Specific Gravity.	Tensile.	Transverse.	Torsion.	Crushing.		
1	West Hallam, Derbyshire	No. 3 melting pig	0·45	1·26	2·60	0·05	0·72	4	5	2	2	4	3·4	Good.
2	” ” ”	No. 2 melting pig	0·60	1·50	2·40	0·06	0·34	6	6	3	1	7	4·6	Good.
3	Weardale Iron Co. . .	Remelted . .	0·13	1·88	2·21	0·10	0·19	12	4	4	21	3	8·8	Good.
4	Lays Iron Works. . .	Hematite . . .	1·14	1·05	3·15	0·05	0·29	2	1	6	43	6	11·6	Good.

If from the results of the chemical analysis we obtain an average for each constituent, we then have what may be considered as a standard of comparison for a typical cast iron, which should possess the maximum of the qualities above enumerated. This gives us:—

Graphite	2·59
Silicon	1·42
Phosphorus	0·39
Sulphur	0·06
Manganese	0·58

It should be pointed out that these numbers are deduced from a most elaborate and careful series of experiments, and that for each constituent they agree very closely with the values recommended in the earlier part of my paper. They illustrate the fact that cast irons of special chemical purity, and also those containing large quantities of metalloids, are alike unsuited for the best class of foundry material, while the intermediate class of iron is especially suited for this purpose. This fact explains why mixtures of different irons, in suitable proportion, produce a far better material in so many cases than the pig iron from which the mixtures are made. There is no virtue in the process of mixing itself, neither is the character of the product influenced by the locality from whence the iron has been derived. The good effect is produced by the blending of the chemical constituents present in such a manner as to ensure the desired result.

My paper has already exceeded the dimensions I anticipated when it was begun, and I cannot therefore now give a systematic summary of the conclusions arrived at; but the following facts will probably be considered proved:—

1. That pure cast iron, *i.e.*, iron and carbon only, even if obtainable, would not be the most suitable material for use in the foundry.

2. That cast iron containing excessive amounts of other constituents is equally unsuited for foundry purposes.

3. That the ill effects of an excess of one constituent can at best be only imperfectly neutralised by the addition of another constituent.

4. That there is a suitable proportion for each constituent pre-

sent in cast iron. This proportion depends upon the character of the product which is desired, and upon the proportion of other elements present.

5. That variations in the proportion of silicon afford a reliable and inexpensive means of producing a cast iron of any required mechanical character which is possible with the material employed.

An interesting example of the effect of very small variations in the amount of sulphur in cast iron has been brought under my notice since this paper was printed. Recently, in the "Transactions of the American Institute of Mining Engineers," a paper has been published by Messrs. Dudley & Pease, entitled "Notes on the Constitution of Cast Iron." The authors are principally concerned with two car wheels, which were poured as nearly as possible at the same temperature, cooled at the same rate, cast in the same kind of mould, were approximately of the same weight, and had been treated as nearly as possible in the same manner in every respect. On examination one wheel proved to be good, while the other was poor. The specimens were analysed, and appeared to agree very closely in composition, the results being as follows:—

	Good Wheel.	Poor Wheel.
Total carbon	3·84	3·53
Graphite	3·30	2·36
Combined carbon	0·54	1·17
Silicon	0·69	0·65
Phosphorus	0·43	0·52
Manganese	0·13	0·12
Sulphur	0·12	0·19

The authors direct attention to the very small difference in the composition of the two wheels, except in the case of combined carbon; and rightly, as I believe, suggest that "the very great difference in the strength of these two wheels is in some way connected with this difference in combined carbon." The iron for this particular application is required to combine a considerable tenacity with the power of receiving a moderate chill; a comparison of the figures I have previously given, when speaking of combined carbon, will show that the poor wheel is too high in this respect. The authors are unable to suggest a cause for the difference in combined carbon, and say, "Evidently some causes as yet unexplained determine the larger amount of carbon in the poorer wheel."

If, however, the remarks which I have previously made concerning the powerful influence of sulphur be true, and if the values I have suggested be correct, then all difficulty in this case vanishes at once. It will be seen that the phosphorus and manganese are present in good proportion, and their variations are not such as to materially alter the character of the product. The silicon is slightly lower in the poor wheel, but in each case it is in small quantity, and this fact renders the influence of a slight variation in sulphur more than usually apparent. In the difference of 0·07 in the percentage of sulphur we have, I believe, the key to the variation of 0·63 in the amount of combined carbon. In the good wheel the sulphur (0·12 per cent.) very closely approaches the limit recommended for best foundry iron, while in the poor wheel the sulphur (0·19 per cent.) very closely approaches the amount met with in hard foundry or mottled pig. Hence, chemical analyses, when rightly understood, afford a good guide to the physical properties of the metal.

DISCUSSION.

Mr. TURNER said he wished to add one word in the absence of Mr. Wood, who, as they knew, had conducted a large number of experiments, using silicon for the purpose of softening and strengthening hard Cleveland iron. Mr. Wood had brought to that meeting a number of specimens which possessed great interest. One was a specimen of cast iron which was made from hard foundry and mottled mixed, softened by the addition of about 10 per cent. of silicon pig. It was cast in a thin sheet, 24 inches + 9 inches + ⅛ inch, and though it was in that thin sheet, it was quite grey. Mr. Wood showed its strength by the fact that it bore his weight readily, while it possessed considerable elasticity. Mr. Turner showed that he could dance on that thin sheet of iron without breaking it.

Sir LOWTHIAN BELL asked if it had been treated in any way—if it had been annealed.

Mr. TURNER said it had not been annealed, nor had anything been done to it, except to put into it the right proportion of silicon, as deduced from the diagram before them (Fig. 3).

The PRESIDENT said he was sure they had all listened with great pleasure to the very admirable paper that Mr. Turner had prepared, and he congratulated him on the capital way in which he had expounded his views. He had done it in a simple, clear manner, with an amount of energy calculated to excite the enthusiasm of his audience, which was a very important point in every man who had to perform the functions of a teacher. The paper contained a great number of statements of very high interest; and to discuss them properly, he had no doubt, would require considerable time—much more than they had at their disposal. Yet, there were certain points of special interest to which some of their friends present had devoted particular attention, and which they had very carefully investigated. He would therefore express a hope that those gentlemen would favour them with their views upon the paper. He would ask Sir Lowthian Bell if he had any remarks to make.

Sir LOWTHIAN BELL, Bart., F.R.S., said he had been engaged the whole of the morning, and had only been able just to glance through the paper, so that he was not sufficiently well read in it to give an opinion upon many of the subjects that it dealt with; but he quite agreed with the President upon the importance of it, and the obligations that they must all feel under to Mr. Turner for the great pains he had taken with the subject of his communication. Down to the present time, perhaps, they had given their attention more to the composition of pig iron intended for the puddling forge and for steelmaking than to the iron required for the foundry, because, as was well known, the presence of a small portion of certain metalloids greatly affected the fitness of the metal for these purposes. Thus, mere traces of phosphorus and sulphur spoiled iron for steelmaking, and were not regarded with favour by the malleable iron manufacturer. The founder had more to consider than the mere strength of the article he made. He had to have an iron which was fluid, and which would run into the mould with great facility; and they knew that, practically, silicon, which might impair the strength of pig iron, was sought for in some cases where a very fluid metal was required. In the meantime, he would cordially support the very warm terms in which the President had commended the paper.

Professor HUNTINGTON said he would like to say one or two words, which, however, would be only of historic interest. In 1882 he had placed at his disposal by the late Sir William Siemens a large electric furnace, worked by five D-2 dynamo machines—one exciting the other four. They were worked by a 12 horse-power (nominal) Marshall's portable steam-engine. Amongst other things that he tried, having such a very high temperature at his disposal, was to see what the effect of varying amounts of silicon on cast iron would be as regards the amount of combined carbon. He took silicious iron, not ordinary cast iron, and melted it in the electric furnace in a bed of retort carbon, so that it was free to take up what carbon it liked. Starting with 10 per cent. silicon pig, in each experiment an increasing amount of ordinary iron was added, in order to find out how much carbon would combine with iron containing a given amount of silicon. He tried a considerable number of experiments, casting pieces roughly about the size of a fist, and allowing them to cool very slowly in sand. These lumps were sent to Wailes' fitting-shops in Euston Road, to be slotted and broken. Some of them were exceedingly hard, as might be supposed, starting with 10 per cent. of silicious iron, but at a certain point they reached a remarkably soft and satisfactory metal, which could be worked under the tool in a way that specially attracted the attention of the engineer who machined it at the shop. They noticed the shading off in quality after that. The result was very interesting, and he intended to pursue the subject further. In a paper which he read at the British Association meeting at Southampton he referred to the fact that he had made these experiments, and intended to go on further with them; but unfortunately when he came to examine the specimens he found that the experiments had not been carried out with sufficient care. The electric engineer who conducted them was a first-rate electrician, but not so much interested in metallurgical work as was desirable. In consequence of that, and the pressure of other work, the subject was not proceeded with. He merely mentioned it as a matter possibly of historical interest, that at that time, in 1882, working with the electric furnace, he found a very remarkable effect produced by the introduction of silicon.

Mr. **Bauerman** congratulated Mr. Turner upon his very interesting paper, which was a valuable compendium of the existing knowledge of the relation between the properties and the composition of cast iron. The author had done well in endeavouring to abolish the foolish notion about an abstract pure cast iron containing only carbon and iron which had been so long current. Much of the confusion of ideas on this subject arose from the habit of considering cast iron and iron castings as synonymous terms—that the properties of the metal run from the furnace, and those of the casting, were identical, which, of course, they were so long as the castings were made direct from the blast furnace, but since the separation of foundry operations from those of smelting this was no longer the case.

There was, in fact, no ideal cast iron of a particular composition, different kinds being required for different purposes. Thus the highly graphitic Scotch pig iron, containing much silicon, was probably the most valuable of all kinds, though in itself worthless for producing castings, its great purpose being to bring up lower qualities of metal to the proper degree of greyness in the cupola. Then there were strong foundry irons, susceptible of chilling, which were as free from silicon as possible, and might be regarded as the highest ideal of cast iron. The author had given 15 tons to the square inch as the maximum tensile strength of this quality in his experiments. In the Antwerp Exhibition some samples were exhibited of castings in the form of thin strips, run direct from the blast-furnace, which were said to be of the tensile strength of 40 kilogrammes per square millimetre (25·4 tons per square inch). These were melted from Nassau red ores with charcoal. The metal used by Gruson for mill-rolls and other chilled castings was of a similar character, and was made in the charcoal furnaces still remaining in the Harz.

The author's notice of the method of obtaining strong mottled iron in Sweden, by the addition of pyrites, required some qualification. The addition was made by the use of a slightly pyritic ore from Jerna, near Stockholm, specimens of which might be seen in the collection at Jermyn Street; and even this was not always necessary, as much of the Swedish magnetic ore contained pyrites in minute quantity, but very closely intermixed, so that if used uncalcined, sufficient sulphur might be introduced to obtain the desired result. The great strength of the Finspong iron, where this method was used, depended, however, upon being tolerably free from silicon and phosphorus. The fact of the association of pyrites accounted for the practice in Sweden—peculiar to that country—of calcining the magnetic ores at a strong chilling heat, in order to desulphurise them as much as possible when the metal was intended for the production of wrought iron.

While on this subject, he wished to call the author's attention to the elaborate series of experiments made at Terre Noire, which were shown and described in a special catalogue in the Paris Exhibition of 1878. Among those was a so-called continuous series from cast iron to steel, in order to determine where the characteristic properties of the latter commenced. In this the maximum strength of cast iron proper was found at about the same carbon limit as that given in the paper, or about 2 per cent. A sample with 2·15 per cent. carbon had a tensile strength of 14¼ tons, and crushed under 80 tons. Those experiments had been most carefully carried out, and deserved to be more generally known than they appeared to be.

Mr. H. **Kirk** said Mr. Turner had given them a very useful paper. He had had scarcely any experience in analysis of pig iron for foundry purposes, but he had lately met with a very extraordinary thing in connection with some castings at his own works, which led him to see that there was a good deal to be learned about it in the way of analysis. He had received a quantity of very bad pig iron; it was hæmatite iron, which had evidently been made under very abnormal conditions in the furnace. The silicon was 3·402 per cent.; the sulphur was 6·26. That iron worked so badly in the forge that he sent it to the foundry, where they used it in the proportion of about one-third in mixture with other iron, and got some good, sound, strong castings, whereas previously, in the same class of castings, they had been troubled with want of strength and with blow-holes. After this inferior pig was worked off, they got some really good pig into the foundry, with silicon ·835 and sulphur ·113 per cent.; and in using that the blow-holes again appeared and spoiled the castings. Since then he had sent some samples of the castings to the chemist to see if he could find out the reason. It was found that the silicon in the good casting was 1·173 per cent; in the bad casting it was ·863 per cent. The sulphur must have been ¼ per cent.* or more in the former, and yet the castings were good and strong. He should pay more attention to this subject than he had hitherto done, and he, for one, felt extremely obliged to Mr. Turner for his valuable paper.

Mr. **Turner**, in reply, said he was much obliged to Mr. Bauerman for several points of information in the remarks which he had made. In connection with the strength of cast iron he had never before heard of a specimen with so high a tensile strength as 26 tons. The highest he had ever heard of hitherto was 20½ tons. But he saw no reason why the strength of cast iron in this country should not be very considerably increased. Founders were at present content with 9 tons; with a little care they could readily bring it up to 12 tons. He believed he could himself make it regularly 15 tons. And when it was remembered that 15 tons was three-fifths of the strength of wrought iron, the importance of such increased strength would be readily seen. By adjusting the chemical constituents of cast iron, and by taking care in foundry practice, a strength of 15 tons might be guaranteed without extra expense. Mr. Bauerman had given support to the idea which he (Mr. Turner) had, viz., that cast iron, as at present made in this country, was not nearly so strong as it might be obtained. With regard to the experiments at Terre Noire, he did not remember to have noticed the specimens to which Mr. Bauerman had referred, but it appeared quite to support the statement made earlier in the paper. The illustration given by Mr. Kirk was exactly in accordance with the curve given on the diagram (Fig. 3), where the maximum general strength was obtained with about 1·4 per cent. of silicon, while Mr. Kirk gave about 1¼ per cent. The difference of course depended upon the amount of other constituents present. They would not necessarily find the most suitable amount of silicon to be always the same, but they would always find its effects on the properties of the metal to follow in the same order.

---

* I have since had the good casting analysed for sulphur, and find only ·155 per cent., which exactly corroborates Mr. Turner's views. Possibly the ·626 of sulphur found in the hæmatite pig was in excess of what there was in the bulk of it, or some may have been lost in melting.—H. K.

Sir **Frederick Abel** regretted that he had been unavoidably prevented from being present during the reading and discussion of this paper, as he had gathered from the concluding observations, which he had heard, that it dealt in a comprehensive manner with a subject to which he had given much attention five-and-twenty years ago, since which time but little addition had been made to our knowledge of the influence of its various constituents upon the properties of cast iron. He might, however, refer very briefly to one or two points connected with the question of the influence of silicon upon the properties of cast iron, which they all knew, as had been already pointed out, to be in the direction of weakening the metal. Many years ago, some time after the completion of the series of investigations conducted under his superintendence on the composition of British pig iron, and of the fuel, ore, &c., employed in its manufacture (the results of which had been largely used by Mr. Turner in his interesting paper), it became necessary, in connection with the manufacture of guns at Woolwich, to ascertain to what extent cast iron would be affected, with regard to its tensile strength, by simple processes of remelting. On that occasion, some very highly silicious descriptions of cast iron were thus treated. He could not now trust himself to say what the proportions of silicon might have been, but he believed in some of the pig iron it almost amounted to 4 per cent., or even higher. Some of those varieties of cast iron were submitted to simple processes of remelting in such a way that the treatment really had very little effect indeed upon the chemical composition of the iron; that was to say, the proportions of total carbon and of silicon were very little reduced indeed, and yet the highly silicious iron was, by repeated remelting, so increased in strength that at last it withstood tensile strains equal to the highest applicable to qualities of iron containing the smallest proportion of silicon that they had to deal with. Unfortunately, this increase of strength was accompanied by a very considerable increase of hardness and decrease of yielding power, and therefore, for the special purpose for which the iron was needed at Woolwich, viz., gun manufacture, this improvement in strength of the silicious iron, which was very interesting from a metallurgical point of view, did not in itself modify the unsuitableness of this particular metal for gun-manufacture. He remembered, when in Berlin in 1855, visiting some works in the neighbourhood where beautiful ornamental iron castings were produced, such as chains, brooches, and other ornaments of a most elaborate character, simply by casting a very liquid iron into carefully prepared sand-moulds. He took some trouble to find out where the iron so employed was obtained, and he found that, after trying various descriptions of iron of German manufacture, and also from Silesia, the best iron they could use was the most highly silicious description of Scotch pig which they could procure. By virtue of its ready fusibility, and its great fluidity, it could be easily manipulated, and flowed readily into the finest portions of the mould, giving the sharpest castings they could produce. It was also interesting to notice, by the way, that in the manufacture of the very elaborate moulds they used by preference a sharp sand which they obtained from Scotland. These one or two points might be of some interest to the meeting in reference to the effect of silicon on iron. He only wished it had been in his power to offer a few remarks upon some other points that he saw were included in the paper.

Mr. CHARLES WOOD remarked, through the Secretary, that he was sorry that at the moment that Mr. Turner's paper came on he was called away, as there were a few remarks which he intended to make that he believed might have been interesting in the discussion. He quite confirmed the results arrived at by Mr. Turner, and thought that a great deal of credit was due to his perseverance and energy in following up his experiments, the results of which, coupled with those mentioned in Mr. Wood's paper read at the Glasgow meeting, were of great importance to the ironfounder.

There was no doubt now that iron could be hardened or softened at will by slight alterations in the proportions of its constituents, and that those could be made at no extra cost to the founder. Another important point was clearly brought out by Mr. Turner, and shown in his tables, which confirmed entirely Mr. Wood's experience and practice, viz., that the same mixture of iron would not give the best results when subjected to tensile, transverse, or crushing strains, as the following would show:—

		Best Mixtures for	
	Tensile.	Transverse.	Crushing.
Graphite	1·62	0·50	0·24
Combined carbon	0·56	1·75	1·85
Silicon	1·96	1·37	0·96

The above results were remarkable, and, as far as Mr. Wood knew, had never been noticed before in any paper, while, although dealing with different iron, they followed his experiments. Another point of great importance to the founder was that many kinds of pig iron, when run into thin castings, such as stove grates, eaves, troughing, and downcomer pipes, would run perfectly white. If a proper proportion of silicon were added to such iron, the castings could be made perfectly soft. The iron would be more fluid, and be less liable to air-holes, whilst the fact of such castings being sufficiently soft to file or cut would be readily appreciated, and this, as before pointed out, without extra cost, whilst heavy castings, which were flexible and not brittle, must be of equal importance. This, indeed, was fully appreciated at the meeting, from the specimens exhibited by Mr. Wood, when Mr. Turner danced upon a cast-iron plate, 2 feet 10 inches long and $\frac{3}{32}$ thick, without breaking. This plate was made from a cupola running sixty tons per day.

It should be understood that each ironfounder must learn what was the quality of the iron that he was using, seeing that other metalloids besides silicon had a remarkable effect upon the strength of the iron, as pointed out in Mr. Turner's paper, and consequently the proportion of silicon might have to be varied with each brand; but there was no doubt whatever that a proper proportion of silicon would soften and strengthen the castings.

The President said they had now reached the final stage of their proceedings, so far as the papers were concerned at all events. The next paper would not occupy long. It was a paper concerning the small ornament or anklet that he alluded to on a former occasion. It was a simple thing, apparently, but he maintained that it was of very high interest. The paper referred to the art of moulding and casting the anklet that he at present alluded to, which was obtained by Mr. Clarke in India. Mr. Clarke had sent, in order to illustrate his paper, the crucible and mould, and to these he thought special attention should be directed. Mr. Clarke was not able to be present.*

---

* Mr. Clarke appeared after the adjournment of the meeting, and described to several members the mould and crucible above mentioned.

ON CERTAIN DESCRIPTIONS OF INDIAN CASTINGS.

By C. PURDON CLARKE, C.I.E., M.R.A.S.
KEEPER OF THE INDIAN SECTION, SOUTH KENSINGTON MUSEUM.

THE importation of partly manufactured material is at present exercising considerable influence over many of the native arts of Oriental countries and India. The supply of machine-made thread has doubled the village handlooms in some districts of Madras, and gold thread from Germany has enabled the brocade weavers to compete with the imitation brocades sent in from Europe.

In some handicrafts, however, the supply of European material has produced a contrary effect. Iron and steel, bar and rod, have displaced an ancient industry, and sheet copper and brass rob the founder of half his work. Formerly the only means of producing sheet metal was by hammering cast plates, an expensive method, only resorted to when thin flat coverings were required for wooden or other objects. For very large vessels, where weight was required to be kept down and strength maintained, hammered sheet was used; but generally the founder was employed, to save as much as possible the labour of forming finished castings, and which required but little beating out, trimming, and brazing.

In the case of a bowl, or flat jar with a narrow mouth, the founder would prepare a cast not unlike in shape and thickness that of an ordinary flower-pot saucer, from which, by constant hammering, the bulbous sides would be formed, projecting beyond the rim, which would remain of its first diameter and thickness. When finished, such a vessel would be nearly double the size of the first cast, and a remarkable example of the native knowledge of the composition of bronzes and annealing processes.

It is worthy of noting that the chief means of detecting modern from old Persian and Saracenic metal vessels is by examining for brazing joints, which in ancient vessels are rare. When not found, a close examination will show the vessel to be a thin casting, the ornamentation being by inlay, or chasing and hammering, which, being done after the cast is made, often gives the reverse side the appearance of chased sheet metal.

So far as I could ascertain, there are three methods of casting practised in India. The first by moulds in sand; the second, moulds in clay not unlike plasterers' piece-moulds; the third, clay moulds formed on a wax model, the *cire perdu* of Europe.

The first of these is well known in Europe, but the second is, I believe, now described for the first time. In preparing the mould, impressions of the various parts of the pattern are taken in clay, and these pieces when nearly dry are, after trimming, stuck neatly together, and kept in place by several layers of mud, in which some fibre is mixed. The mould when ready has but one vent, which, placed on the most convenient side, is carried up into a sort of bottle neck. If the object is small several moulds are attached together, and the vents united by a single short neck of clay, to which a crucible, enclosed in an egg-shaped ball of clay, is attached. The size of this crucible depends upon the exact amount of metal required to fill the mould or moulds; and this quantity being known by experience, the founder places it inside before closing up. No provision is made for the escape of air from the mould when the metal is poured in. The mould and crucible (now in one piece) is allowed to dry; and after several coats of clay, tempered with fibre, have also been well baked on by the sun, the furnace is prepared. This is simply a circular chamber about 2 feet 6 inches in diameter, 2 feet in height, with a perforated hearth and no chimney. Half filled with charcoal, a good heat is obtained by the use of several sheepskin bellows from beneath. When ready, as many moulds as the furnace will hold are placed in it, the crucible end of each being embedded in the fire. A cover is placed over, and the fire kept up until, upon examination, the moulds are found to be red hot. They are then taken, one at a time, and replaced in a reverse position, the crucibles being now above. The metal flows down into a red-hot mould, and penetrates the finest portions of the surface without suffering from air or chilling. The fire is allowed to gradually cool, and when the objects are broken out of their clay covering, the metal is soft and malleable.

The third manner of casting (that by the use of a wax pattern which is destroyed in the moulding) is well known, but in one particular case the process has been carried further than would be at first believed, and of this I will now attempt a description.

The object produced is an anklet, a flexible ring about 4 inches in diameter, made from an endless curb chain. Such curb chain trinkets are common in India, and are generally made from thick silver wire rings interlinked and soldered one by one. In this example the anklet is of bronze, and consists of a complicated chain of 43 detached links, the whole being cast by a single operation. The first part of the process is the preparation of a pattern in wax, a delicate work, each link having to pass through four others, and to bear three small knobs or rosettes. These are in two instances but ornaments; the third, however, serves as a channel for the metal to enter each ring.

Then commences the most difficult part of the work, each ring having to be slightly separated, and this is effected by painting in a thin coat of fine clay until there is sufficient to form a partition. Other coats of clay are added until a thickness of about half an inch is attained, when a groove is cut round the upper side of the ring, and deepened until the row of knobs is bared. The wax is then melted out, and the mould attached to a crucible as before described. When cast, and the mould broken away, the chain comes out inflexible, being attached to a rod which runs round where the groove was cut. This is broken off, and the chain is complete.

Having been consulted respecting the trades to be represented in the Indian courts of the Colonial and Indian Exhibition, I recommended amongst others a good brassfounder to be sent. Dr. Tyler, who was charged with the collection of these artisans, engaged one of the best he could find, but up to the present the foundry is not in working order.

I submit for your inspection one of these combined crucible moulds, with fragments of another, also a cast curb chain anklet; and now conclude by thanking you for this opportunity of publishing an interesting process.

DISCUSSION.

The PRESIDENT said he had very great pleasure in presenting the thanks of the meeting to Mr. Clarke for taking so much trouble in obtaining the specimens illustrative of his paper. They were of great interest, and very well worth considering carefully. The mould and crucible were fixed together. He would be very glad to hear any remarks upon this subject. He believed Mr. Clarke had had an opportunity of seeing a great many interesting metallurgical processes in India. He had been very much struck with one of the points mentioned, namely, the frequent use that was made in India of very highly heated moulds, and that was a subject which he thought was deserving of considerable attention. He supposed they could hardly expect much discussion upon a point of this kind, which was rather fitted for the examination of the objects than otherwise.

The following papers were taken as read:—

ON EXPERIMENTS MADE WITH STEEL RAILS IN RUSSIA.

BY M. BECK-GUERHARD, ST. PETERSBURG.

IT is now ten years since the manufacture of steel rails was begun in Russia. The development of the trade has been rapid and considerable. There are at present eight works manufacturing steel rails throughout the empire, two being at St. Petersburg, two in Poland, one in the centre, one in the south, and two in the Ural. These eight works have a united production of over 200,000 tons of rails per annum, which is a quantity calculated to be rather in excess of the actual requirements of the country.

Both Bessemer and Siemens steel is used in the rail manufacture, the works in question also producing fastenings, tyres, axles, bars, and plates, &c., for shipbuilding.

In 1877 the Ministry of Ways of Communication issued certain instructions in reference to the testing of steel rails. The tests determined upon have already been printed in our *Proceedings.** The severity of the Russian winter, and the great variations of temperature, determined the Department having charge of this subject to order that it was desirable, that, in the manufacture of steel rails, care should be taken to have them sufficiently mild. The following test, viz., 30 poods = ½ ton, from 7½ feet to 8½ feet, according to section, was fixed as the regular test for rails, which were to be previously frozen in a mixture of ice and salt to a temperature 12° R. The softness of the rails was to be determined by testing under a press, a permanent set of one mm. being prescribed under a weight which rose or fell according to the section.

Under these circumstances, the Russian steel works undertook the production of rails of a milder description than the rails generally manufactured abroad. It was found that rails so produced from soft steel resisted the influence of a low temperature better than the rails manufactured from steel of a harder description, and the result has been that broken rails have not been nearly so frequent, even in the severest frost, as they were a few years ago when the steel made use of was harder.

---

* See the *Journal of the Iron and Steel Institute*, No. I. 1883, p. 468.

Notwithstanding what seemed to be the obvious advantage of using softer steel for rails that were intended to resist great variations of temperature, it was discovered by the Russian Railway Administration that a number of the rails produced from the soft ingot metal gave way after a very limited period of service. This defect was to some extent explained by having too short ends cut off the bar, leaving the extremities hollow, or by the use of too heavy locomotives, or by inadequate ballasting; and to meet these several difficulties, and others that came under their notice, the Russian railway engineers considered whether it would not be advisable to somewhat increase the hardness of the rails used in the permanent way.

With a view to furnishing data for the determination of the problem just stated, the Imperial Russian Technical Society undertook to carry out a series of experiments on the wear of rails relative to their hardness, on something like the lines that were adopted by Dr. Dudley in his well-known investigations on behalf of the Pennsylvania Railway. For this purpose the Russian Technical Society appointed a special commission of experts from their own body, which issued to all the Russian Railway Administrations a circular-letter requesting to be furnished with samples of rails not shorter than 10 feet in length, as well as tyres of both Russian and foreign make, with a description of each specimen submitted, giving, among other facts, the following:—

1. The works at which the rails were manufactured, and the date of their manufacture.
2. The date at which the rails were laid down.
3. The form of the rails, and their original weight.
4. The average weight of each locomotive axle.
5. The tonnage that had passed over the rail.
6. The weight of the rail after removal from the permanent way.
7. The condition of the rail when so removed, as, whether broken, flattened at the ends, cracked, or otherwise.
8. The position of the rail in the permanent way, as whether placed on a straight line or a curve, outside or inside, &c.
9. The description of the fracture or breakage.

mber and height of blows, and of the pressure under permanent set must be=0, were proposed and submitted ister of Ways of Communication.

an injector nozzle. This is done, but this alone is not for accurate reading of the temperature, because the blast is never continuous at the same pressure.

The first operation, therefore, is to throttle down the blast by means of a cock (H) to a given pressure, which should always be maintained at the same suitable height, and which is indicated on the gauge E. When this is done, the velocity of the hot air through the apparatus is constant, and the amount of cold air sucked in will also be constant.

Now, in order to calculate the value of the reading on the scale of the thermometer C, it is necessary to ascertain the coefficient. This is done by first ascertaining, by the Siemens copper-ball pyrometer, the true temperature of the blast.

We then have

H = temperature of the hot blast.
F = temperature of the mixture streaming out of the apparatus.
A = temperature of the cold air sucked in.
C = Coefficient to be ascertained. And

$$C = \frac{H - A}{F - A} \qquad H = C\,(F - A) + A$$

Notwithstanding the most careful manufacture, it has been found impossible to make the instruments accurate, so that the indications of several pyrometers placed under equal conditions are exactly the same. It is, therefore, necessary to determine the coefficient for each apparatus by means of the Siemens copper-ball pyrometer, and if this adjustment, which is easily done, has been once made, the indications of the instrument will be perfectly exact.

In fastening the pyrometer it is necessary to allow free movement to the instrument, as otherwise the expansion from the heat will cause the flanges to break. It should also be wrapped in a bad conductor of heat (as, for instance, slag cotton) for protection against different radiations at different outside temperatures.

VOTES OF THANKS.

Mr. E. **WINDSOR RICHARDS** begged to propose "that the best thanks of the Iron and Steel Institute be and are tendered to the President and Council of the Institution of Civil Engineers for their courtesy in granting the use of their hall for the present meeting."

Sir **LOWTHIAN BELL**, F.R.S., seconded the motion, which was carried by acclamation.

Sir **HENRY BESSEMER**, F.R.S., said that before they left there was one other duty to perform, which he was sure would be a very pleasant one, and without expatiating upon the subject he would move, "that the most cordial thanks of the Iron and Steel Institute be tendered to Dr. John Percy, F.R.S., for the admirable way in which he has presided over the present series of meetings."

The resolution was duly seconded, and carried by acclamation.

The **PRESIDENT** thanked the members sincerely for the manner in which they had been pleased to accept this proposal by his friend, Sir Henry Bessemer. He was perfectly conscious that he had been guilty of several shortcomings, and, moreover, he had the misfortune to labour under a little laryngeal irritation, which he had no doubt had made it extremely disagreeable on the part of the members to listen to his voice.

He had now to inform them that it had been decided to hold the next meeting of the Institute in London. Having regard to the fact that this year was memorable from the circumstance of the meeting of so many of their Colonial and Indian fellow-subjects in London, the Council had reason to believe that many of their members would wish to come into personal contact with some of those gentlemen, especially such as might be engaged in the metallurgical business of the world. It was, therefore, presumed that such an arrangement would meet the general wish of the Institute. With these remarks, he begged to pronounce the present meeting terminated.

APPENDIX.

◆

DISCUSSION ON MR. BLAIR'S PAPER "ON CERTAIN ACCESSORY PRODUCTS OF BLAST FURNACES" (Page 81).

MR. DICK remarks, through the President, that when a portion of the slag, about one-eighth of an inch in thickness, is exposed to the action of hydrochloric acid during some days, the crystals of gehlenite are completely gelatinised, sulphuretted hydrogen being slowly evolved during the whole time. When the gelatinised mass is boiled in caustic potash or carbonate of potash, or exposed to hydrofluoric acid, it leaves a residue of a faint blue colour. Examined under the microscope, the residue is seen to consist of octahedra, more or less modified, mostly colourless, but many are blue, and a few pink. They are said to be spinels. Many of them are seen to have been formed on spiculæ of the red compound of titanium found in blast-furnace bottoms.

Seen by reflected light, these spiculæ resemble millerite. They are sometimes in groups wholly enclosed within the spinels, but in most cases project beyond the spinels, sometimes going through them, and projecting from both sides into the adjoining gehlenite crystals, and in one instance Mr. Dick saw into an adjoining cavity.

Besides these spiculæ, the spinels are seen to contain other enclosures, some of which resemble coralline bodies, others more resemble preserved ginger in form and colour, whilst others, again, are more or less spherical detached bodies. When the spinels are crushed in an agate mortar, and moistened with hydrochloric acid, they evolve sulphuretted hydrogen from these enclosures. Similar enclosures occur in the crystals of gehlenite, and are seen to dissolve with brisk effervescence of sulphuretted hydrogen in hydrochloric acid under the microscope. In some cases a residue of gelatinous silica remains, which may be from mother-liquor slag or from some of those silicates which, when dissolved in hydrochloric acid, evolve sulphuretted hydrogen.

In a small portion of the slag analysed by Dr. Percy many years ago, which gave the formula of gehlenite, no crystals of spinel were found, and only a small quantity of lance-shaped spiculæ of titanium and abundance of the bodies gave sulphuretted hydrogen. From the absence of spinels in one specimen of gehlenite, and their presence in another, it would seem that one cannot deduce their existence from the composition of the slag alone. Perhaps, when the spinels are analysed, it may be proved that some element, such as zinc, is present in one slag and absent in the other.

[I have pleasure in stating that my friend, Mr. Dick, has shown me his preparations under the microscope, in which I was greatly interested, especially as to the mode of existence of sulphur.—J. P.]

APPENDIX B.

THE IRON AND STEEL INSTITUTE.

STATEMENT OF ACCOUNT FOR THE YEAR ENDING DECEMBER 31, 1885.

RECEIPTS.

To Balance on December 31, 1884—		
Invested	£2998 13 1	
On Deposit with N.P. Bank of England	491 12 8	
		3490 5 9
,, Entrance Fees	147 0 0	
,, Subscriptions	2364 12 0	
,, Journals, &c., sold	142 0 11	
,, Interest	126 7 6	
		2780 0 5
		£6270 6 2

EXPENDITURE.

By Salaries of Secretary and Clerks	£696 0 0	
,, Office Rent, Cleaning, &c.	334 17 10	
,, Editing and Translating	154 4 0	
,, Expenses in connection with Annual Meeting in London, May 1885	84 16 5	
,, Expenses in connection with Meeting at Glasgow, September 1885	114 17 6	
,, Journal Publishing Expenses	616 13 5	
,, Printing, Advertising, and Stationery	176 13 4	
,, Insurance	1 2 6	
,, Postages, Receipts, &c., per Treasurer and Secretary	77 1 1	
,, Sundry Payments	42 6 6	
		2248 12 7
,, Balance—		
Invested in £733 North-Eastern-Darlington 5¼ per cent. Stock, at a cost of	£999 12 6	
Invested in £1546 Scinde, Punjaub, and Delhi 5 per cent. Stock, at a cost of	1999 0 7	
	£2998 13 1	
On Deposit with N. P. Bank of England	500 0 0	
To credit of Current with do.	523 0 6	
		4021 13 7
		£6270 6 2

DAVID DALE, *Treasurer.*

OBITUARY.

MR. EDWARD WILLIAMS.

AT page 33, *ante*, the presentation by the Council of the Iron and Steel Institute of the Bessemer medal to one of its most distinguished members—Mr. EDWARD WILLIAMS of Middlesbrough—in recognition of his eminent services to the iron and steel trades, is recorded; and now the sad duty devolves upon us of chronicling his death, which took place at his residence, Cleveland Lodge, Middlesbrough, on the 9th of June last. By his decease, the Iron and Steel Institute has lost one of its most zealous supporters. An original member, the chairman of the meeting held in Newcastle-upon-Tyne to establish the Institute, a member of the Council from the first, a member of the Puddling Committee appointed to investigate the subject of Mechanical Puddling, and a past President—Mr. Williams was well known to many of the members of the Institute, and his presence will be much missed at the meetings, at which he always took an active part.

The son of Mr. Taliesin Williams, a schoolmaster and author, of Merthyr Tydfil (himself a son of Edward Williams, better known as Iolo Morganwg of Welsh literature), Mr. Edward Williams was born in that town on February 10, 1826, and had, therefore, only completed his sixtieth year when he was taken from a life of usefulness and activity, not only in the trade with which he is so strongly identified, but in the town of Middlesbrough, where he passed the last twenty years of his life, and where he occupied a very prominent place, which will not be easily filled.

Mr. Williams was educated at his father's school, and in 1842 entered the service of the Dowlais Iron Company, in which he continued until 1864, rising during that period to the position of second in command of the works, to whose prosperity, as has been recently testified by Mr. G. T. Clark, he so greatly contributed, bringing, as Mr. Clark stated when the Institute held its meeting in Wales, "their mills and forges to a state of perfection never before attained."

It was during the period of his service with the Dowlais Company in 1856 that Mr. Williams was attracted by the paper read by Sir Henry Bessemer (then Mr. Bessemer) at Cheltenham before the British Association, which was reported in the *Times* on the day following its reading (Wednesday). He was struck by the novel proposal, and, with the energy which always characterised him, resolved to try whether it was a great fact or a great fallacy. He built a small fixed converter, and on the following Saturday rolled a bar of iron—the first ever rolled from the Bessemer process. A portion of this bar was exhibited by Sir Henry Bessemer at the Inventions Exhibition in 1885, and is now preserved at the offices of the Institute, with other specimens presented by Sir Henry. After the Dowlais Iron Company took out a license to work the new process, Mr. Williams devoted much time and energy to making it a success, but owing chiefly to the want of knowledge of the effect of phosphorus in iron and steel, which was then general, the experiments were eventually abandoned. Mr. Williams, however, rolled, from blooms sent to Dowlais by Sir Henry Bessemer, the first steel rails ever made, and he never ceased to be much interested in, and a strong upholder of, the Bessemer process.

In 1864, Mr. Williams left Dowlais to manage the house of Guest & Company, in London; but in 1865 he was offered, and accepted, the position of general manager to the new firm of Bolckow, Vaughan & Co., Limited. For this position his energy and determination, and his thorough and practical knowledge of his business, eminently fitted him; he held it for ten and a half years, during which time the firm prospered greatly, and extended its operations widely. While with Bolckow, Vaughan & Co., Mr. Williams established the Gorton Steelworks, near Manchester, and he was busily engaged with the Eston Steelworks when he severed his connection with the company. He then entered into business as an ironmaster on his own account, becoming the proprietor of the Linthorpe Ironworks at Middlesbrough.

Mr. Williams designed and established for Messrs. Crawshay Brothers the new Bessemer steelworks at Cyfarthfa, which are considered, in point of arrangement and suitability for economical working, equal to the best in this or any country, and are among the most recently erected in the kingdom.

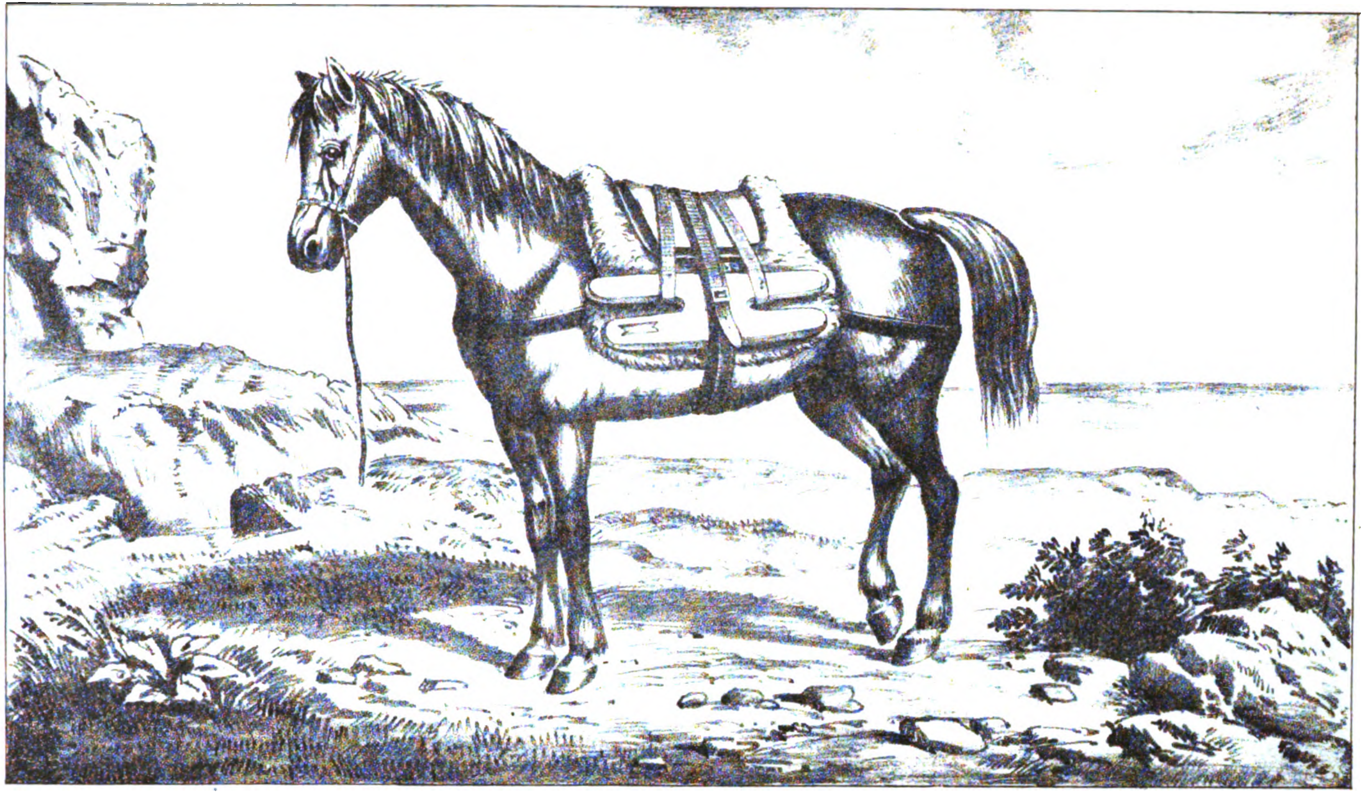
It is needless to say much here of Mr. Williams' connection with the Iron and Steel Institute. He was always deeply interested in its welfare, and anxious that it should carry out the purpose for which it was established, so as to be an active and useful means of assistance to those engaged in metallurgical industries. In 1857, along with some other leading Welsh ironmasters, Mr. Williams was a founder of the South Wales Institute of Engineers, an active and prosperous undertaking. He was also an active worker in all kinds of trade organisations. He was President of the North of England Ironmasters' Association in 1868, and again in 1884–85. He was also President of the Iron Manufacturers' Association, and took a great interest in the Board of Arbitration for the Manufactured Iron Trade of the North of England from the date of its formation in 1869. He was one of the masters' representatives on the Standing Committee of the Board almost from its foundation, and he sat as arbitrator, along with Mr. A. J. Mundella, in the wages dispute that occurred in 1876, and again in 1878. Mr. Williams bore a high reputation for his knowledge of ironworks' engineering, and was consulting engineer to several companies.

As a business man the deceased was regarded as most upright and straightforward, and all who came into intimate contact with him bear testimony to his sterling worth.

Mr. Williams had many friends among the members of the Iron and Steel Institute, and his death, at an age when he might have looked forward to years of the work in which he was so deeply interested, will be widely deplored. As one of the best practical ironmasters (as Sir H. Bessemer called him at a recent meeting), he leaves a vacant place at the Council which will not be easily filled, and as a man pre-eminently genial, having an excellent heart, and ready to do a kindness to everybody, he will be sincerely regretted by all who knew him.

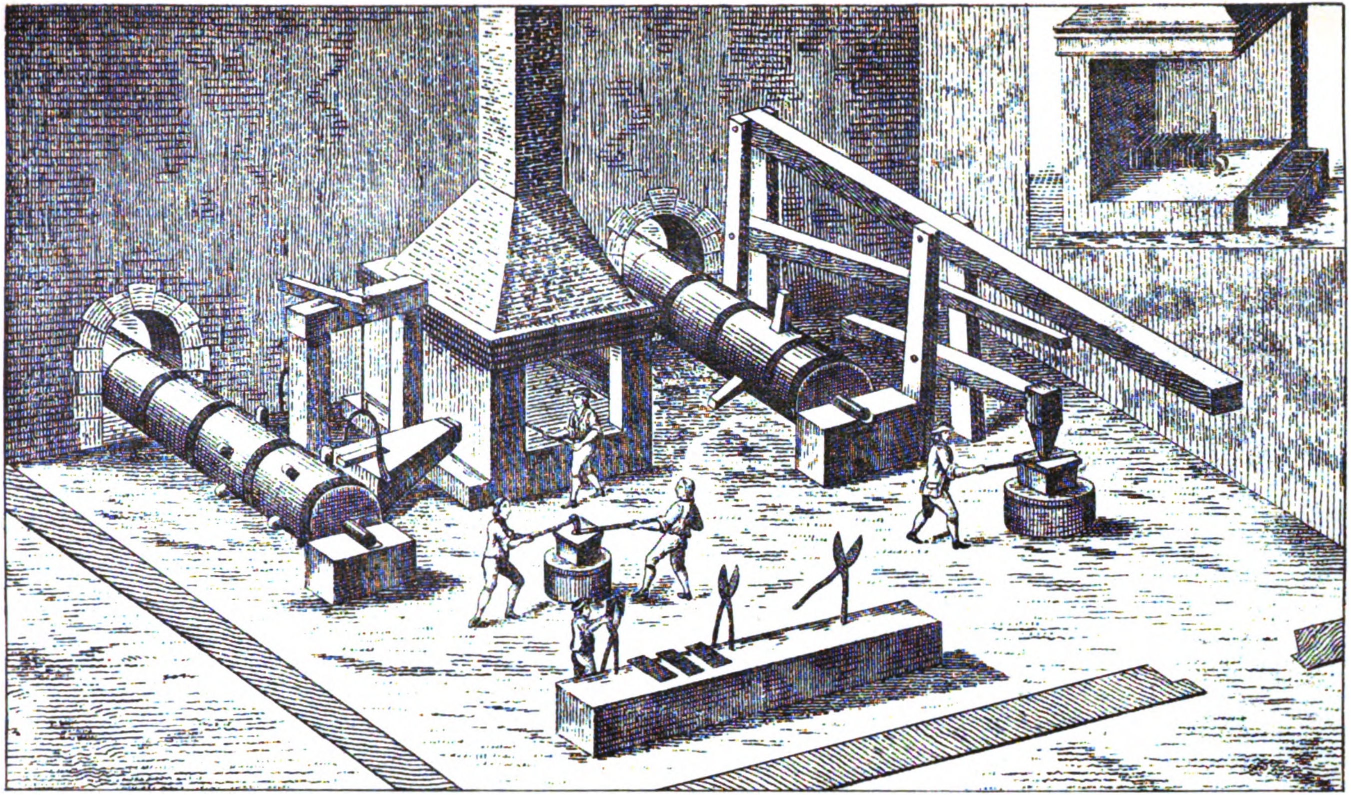
In Middlesbrough, the town of his adoption, Mr. Williams is deeply mourned, both for his practical benevolence, and for his interest in all matters relating to the prosperity of the town and his fellow-citizens.

TO ILLUSTRATE MR. FLOWER'S PAPER.



SIR HENRY JAMES' ILLUSTRATION OF A HORSE CONVEYING TIN ACROSS GAUL.

Ballantyne, Hanson & Co. Edinburgh & London.

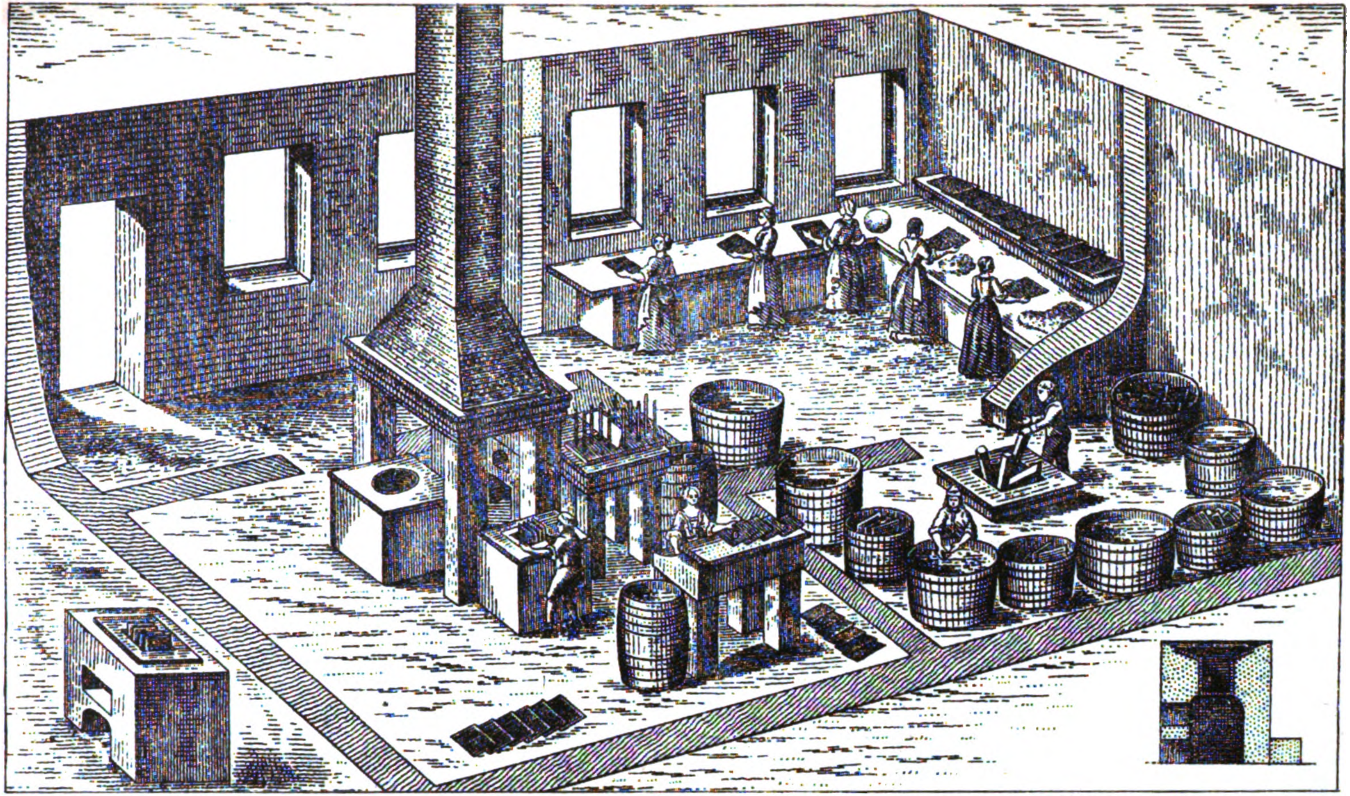


MANUFACTURE OF SHEET IRON IN 1714.

urnal of the Iron & Steel Institute

Ballantyne, Hanson & Co. Edinburgh & London.

TO ILLUSTRATE MR. FLOWER'S PAPER. PLATE III.

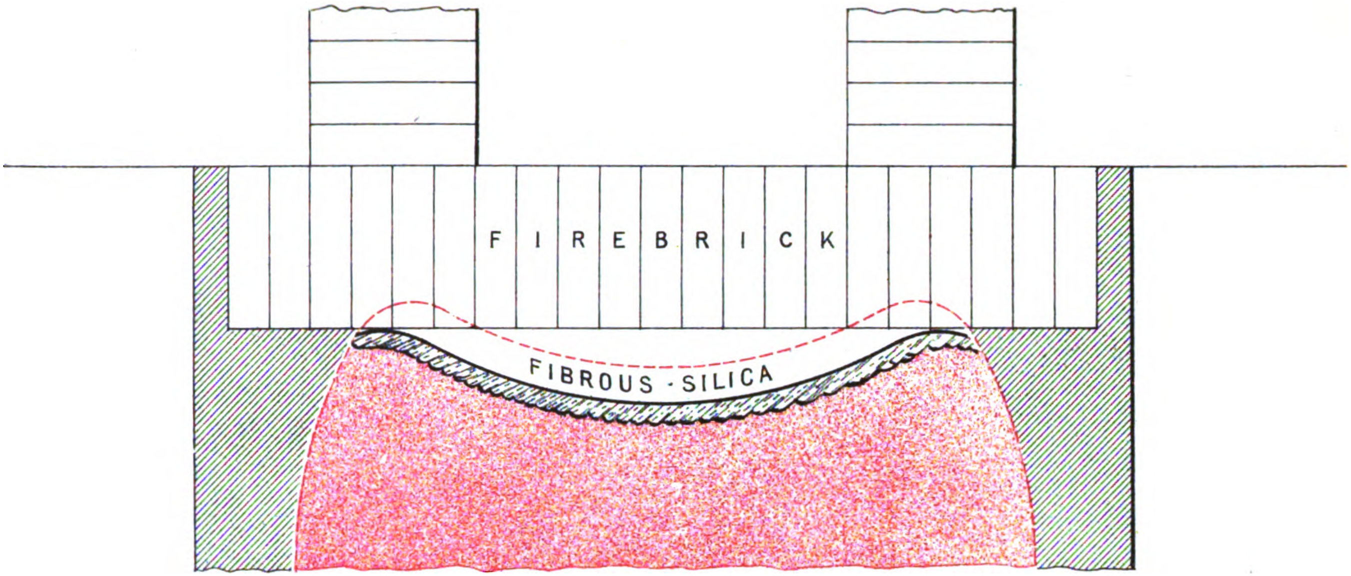


MANUFACTURE OF TIN PLATES IN 1714.

Ballantyne, Hanson & Co. Edinburgh & London.

TO ILLUSTRATE MR. BLAIR'S PAPER.

PLATE IV.



DESCRIPTION OF DIAGRAM.

The original form of the furnace hearth is shown in black. The red dotted lines show the shape and position of the bear. The portion of the bottom under and surrounding the firebrick was originally of Mansfield sand rammed hard.

The unshaded portion at the top of the bear was chiefly metal, whilst the lower part, coloured red, was a conglomerate such as is usually found under blast furnaces. The intermediate layer shows the place in which the fibrous silica was found.

Ballantyne, Hanson & Co. Edinburgh & London.

PLATE V.

TO ILLUSTRATE MR. BAUERMAN'S PAPER.

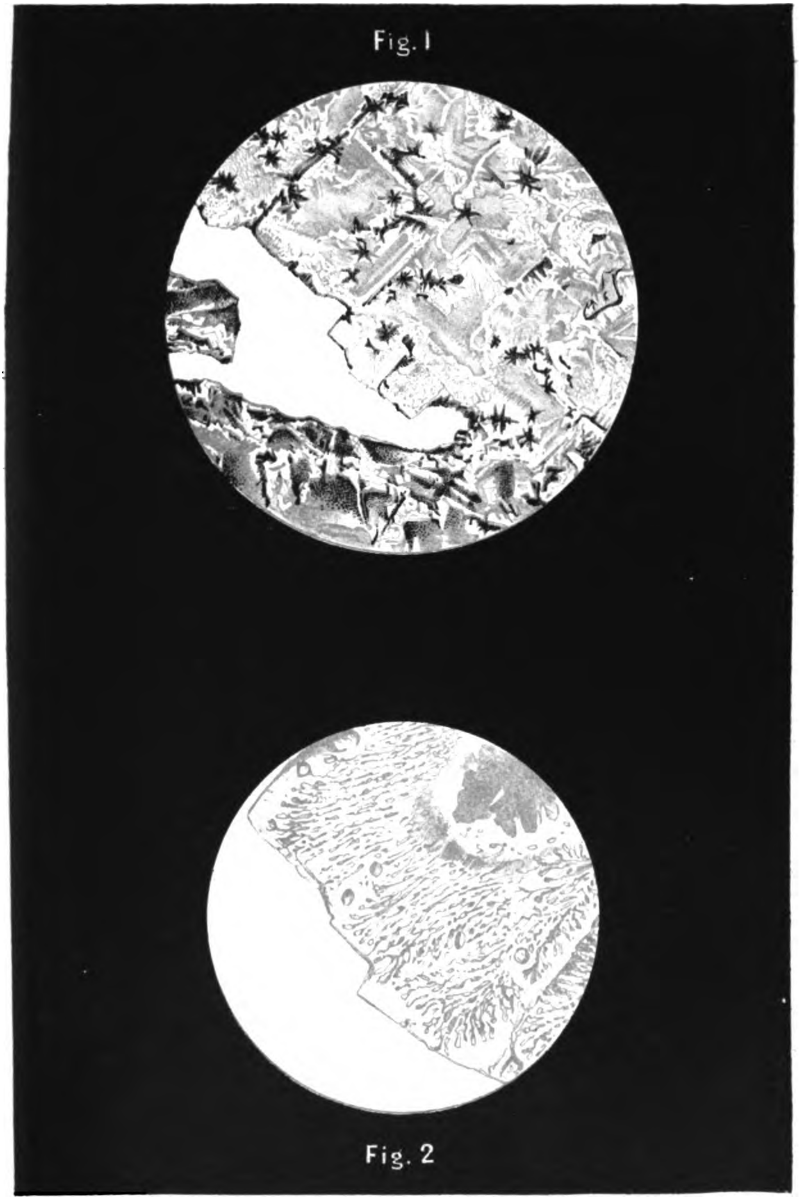


Fig. 1

Fig. 2

Frank Rutley. Delt.

Gehlenite Crystals in Blast Furnace Slag.

Fig. 1 × 25 diam. **Fig. 2** × 120 diam.

Journal of the Iron & Steel Institute
Ballantyne, Hanson & C° Edinburgh & London

TO ILLUSTRATE MR. HEAD'S PAPER.

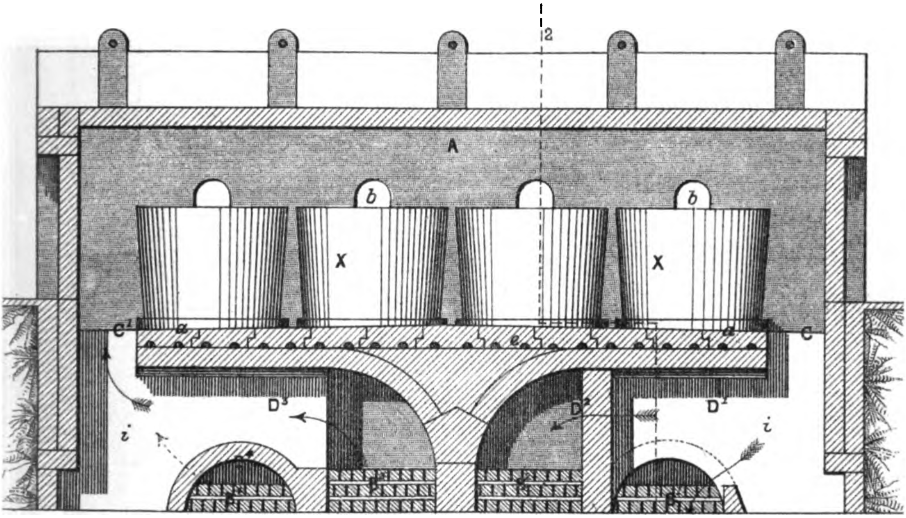


Fig. 1.

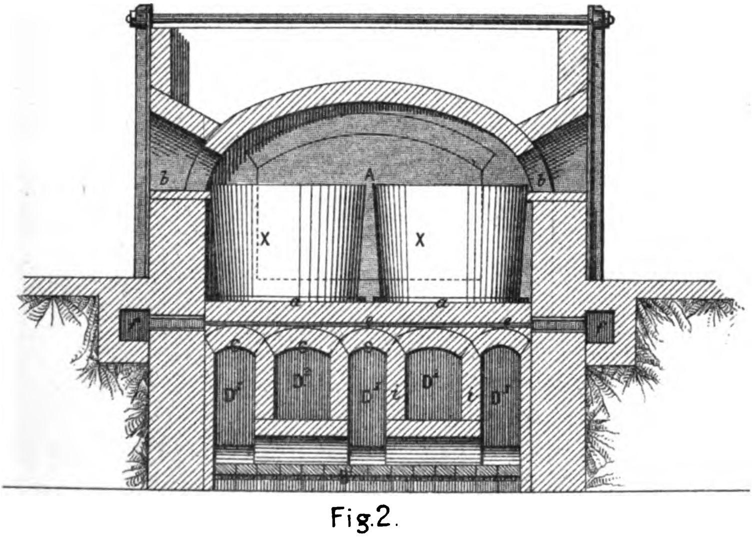


Fig. 2.

Ballantyne, Hanson & Co. Edinburgh & London.

TO ILLUSTRATE MR. HEAD'S PAPER.

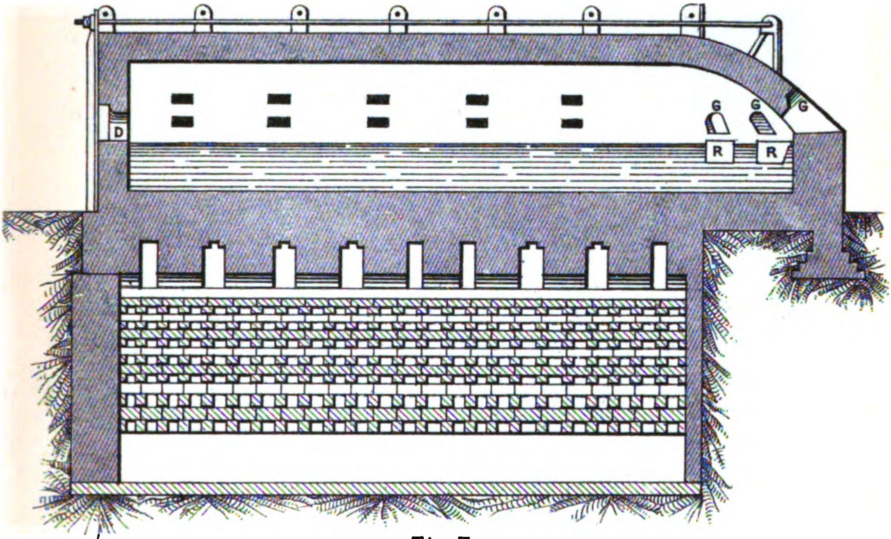


Fig. 3.

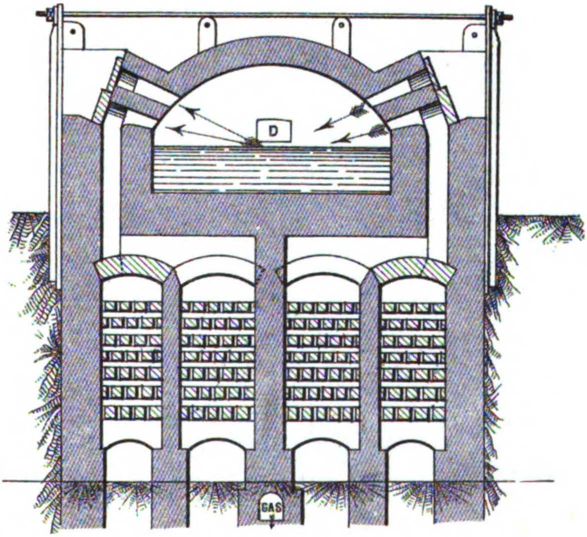


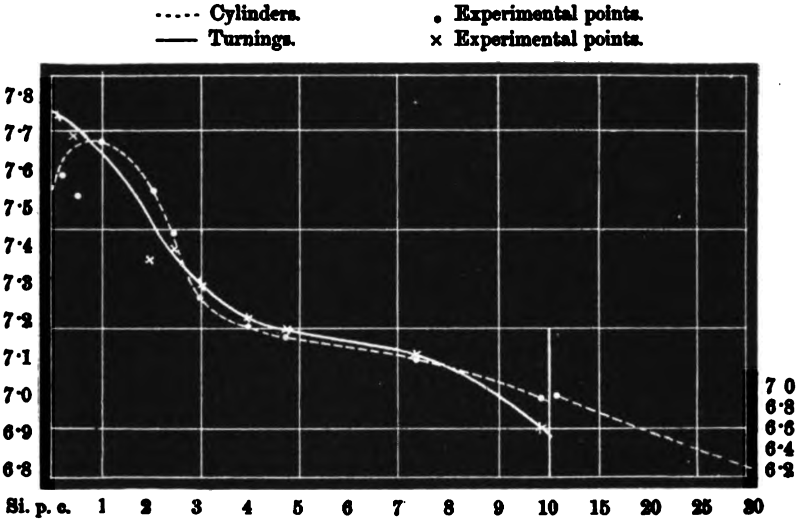
Fig. 4.

Ballantyne, Hanson & Co. Edinburgh & London.

PLATE VIII.

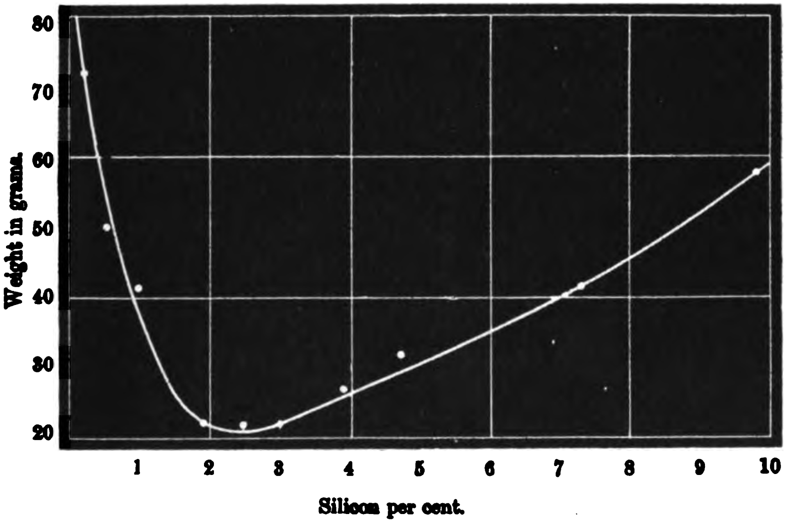
TO ILLUSTRATE MR. TURNER'S PAPER.

FIG. 1.—RELATIVE DENSITY.



In Fig. 1 Relative Density is expressed graphically, the curve being continued, on a reduced scale, with data obtained from *Watts' Dictionary*, 1st Suppl., p. 753, where an account is given of some silicides of iron prepared by Hahn.

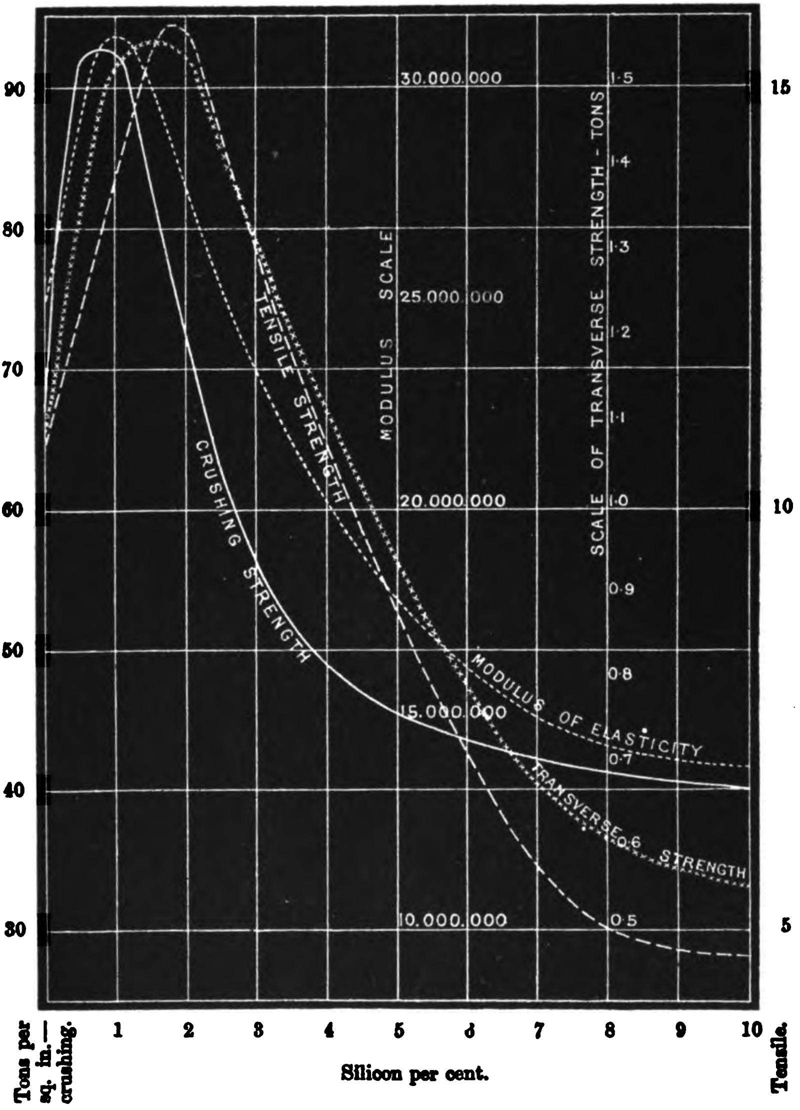
FIG. 2.—RELATIVE HARDNESS.



Ballantyne, Hanson & C° Edinburgh & London.

TO ILLUSTRATE MR. TURNER'S PAPER.

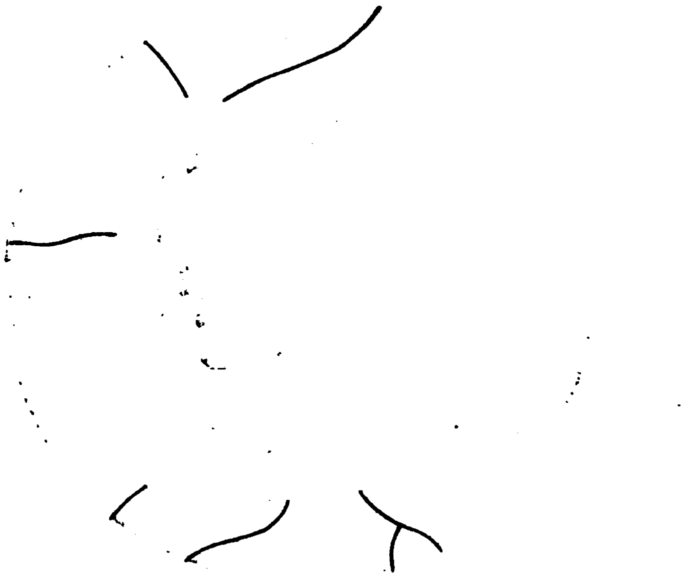
Fig. 3.—Effect of Silicon on Cast Iron—Crushing, Transverse, and Tensile Strength, with Modulus of Elasticity.

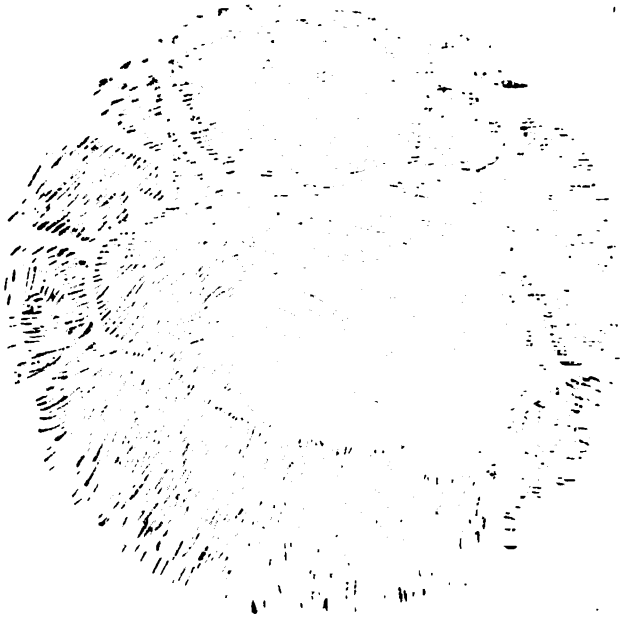


Journal of the Iron & Steel Institute

Ballantyne, Hanson & Co. Edinburgh & London.

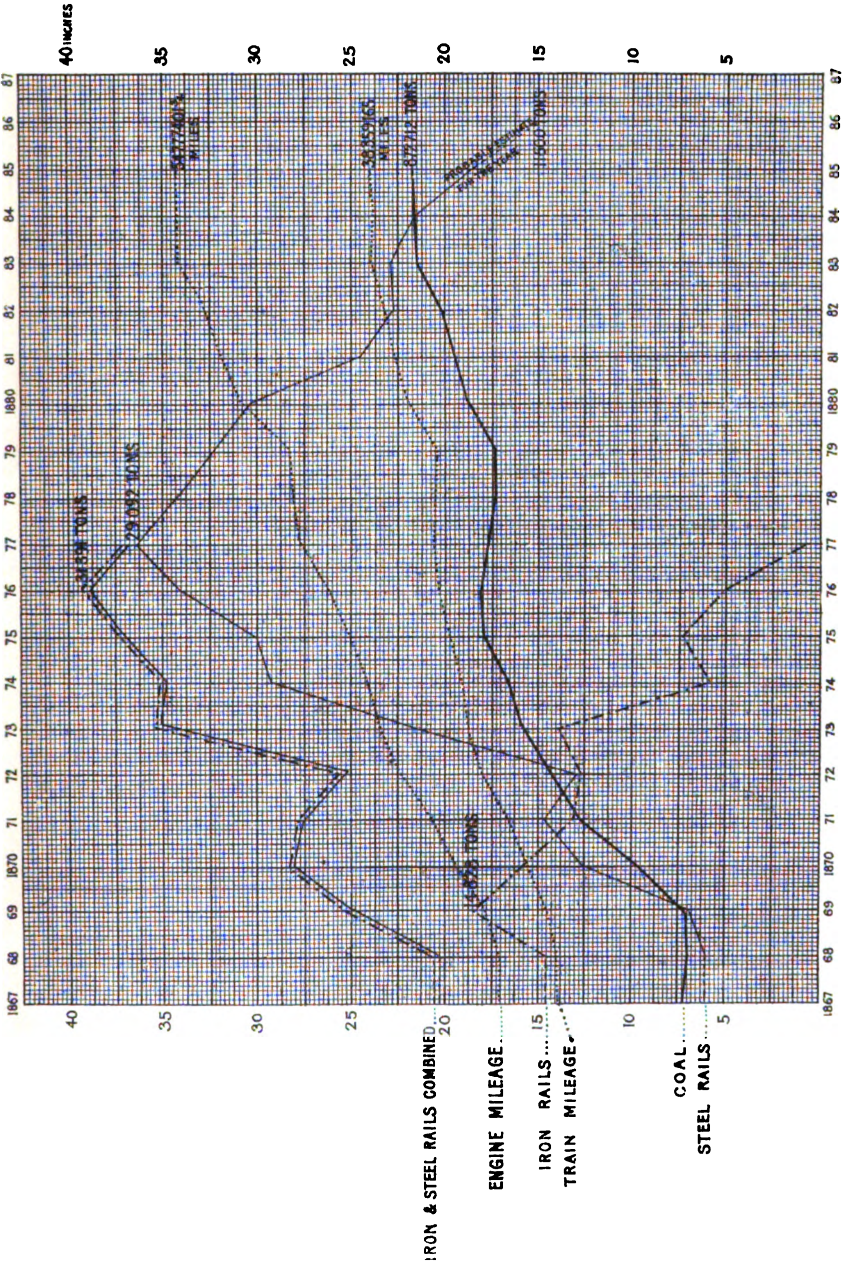
TO ILLUSTRATE DR. SORBY'S PAPER.





Ballantyne, Hanson & Cº Edinburgh & London

TO ILLUSTRATE MR. WEBB'S PAPER.



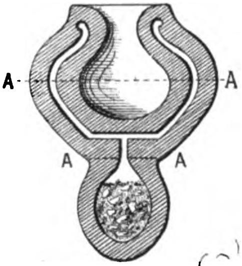
Ballantyne, Hanson & Co. Edinburgh & Lon

PLATE XII.

TO ILLUSTRATE MR. PURDON CLARKE'S PAPER.

INDIAN CASTINGS.

Fig. 1.



A.A. Joints in moulds

Fig. 2.

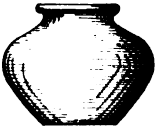


Fig. 3.

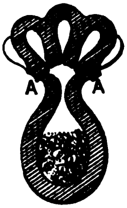
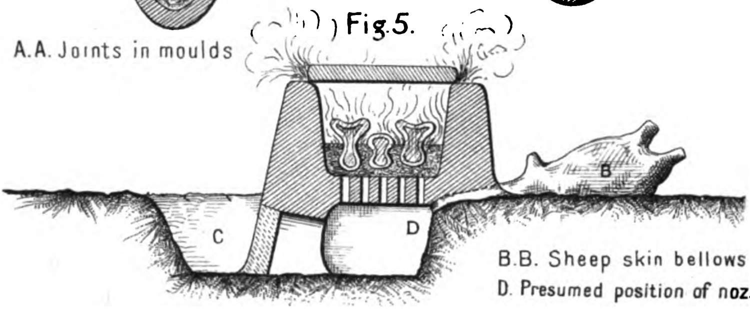


Fig. 4.

Fig. 5.



B.B. Sheep skin bellows
D. Presumed position of nozzle.

C. Opening luted up during firing

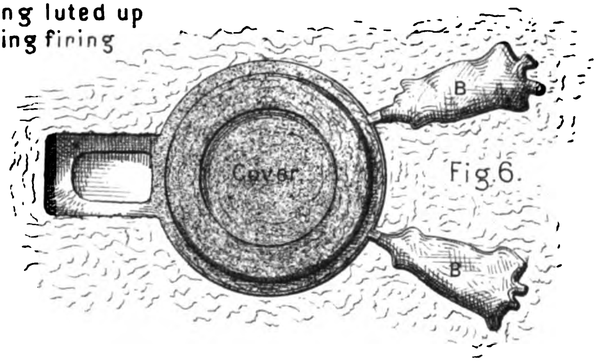


Fig. 6.

Fig. 1. Mould with crucible attached for a brass jar, Lahore.

„ 2. Brass jar, finished.

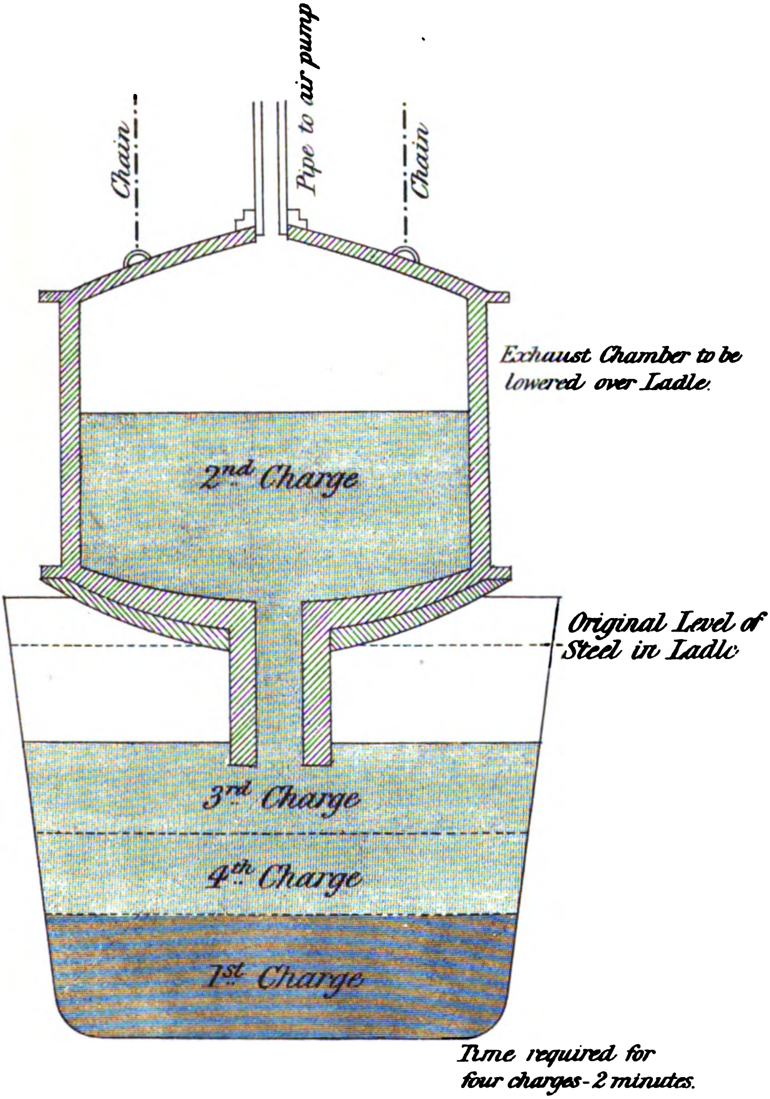
„ 3. Mould and crucible for several small trinkets, Agra.

„ 4. Bezil of a toe ring from mould, fig. 3.

„ 5 and 6. Section and plan of furnace, Lahore.

Journal of the Iron & Steel Institute
Ballantyne, Hanson & Co. Edinburgh & London.

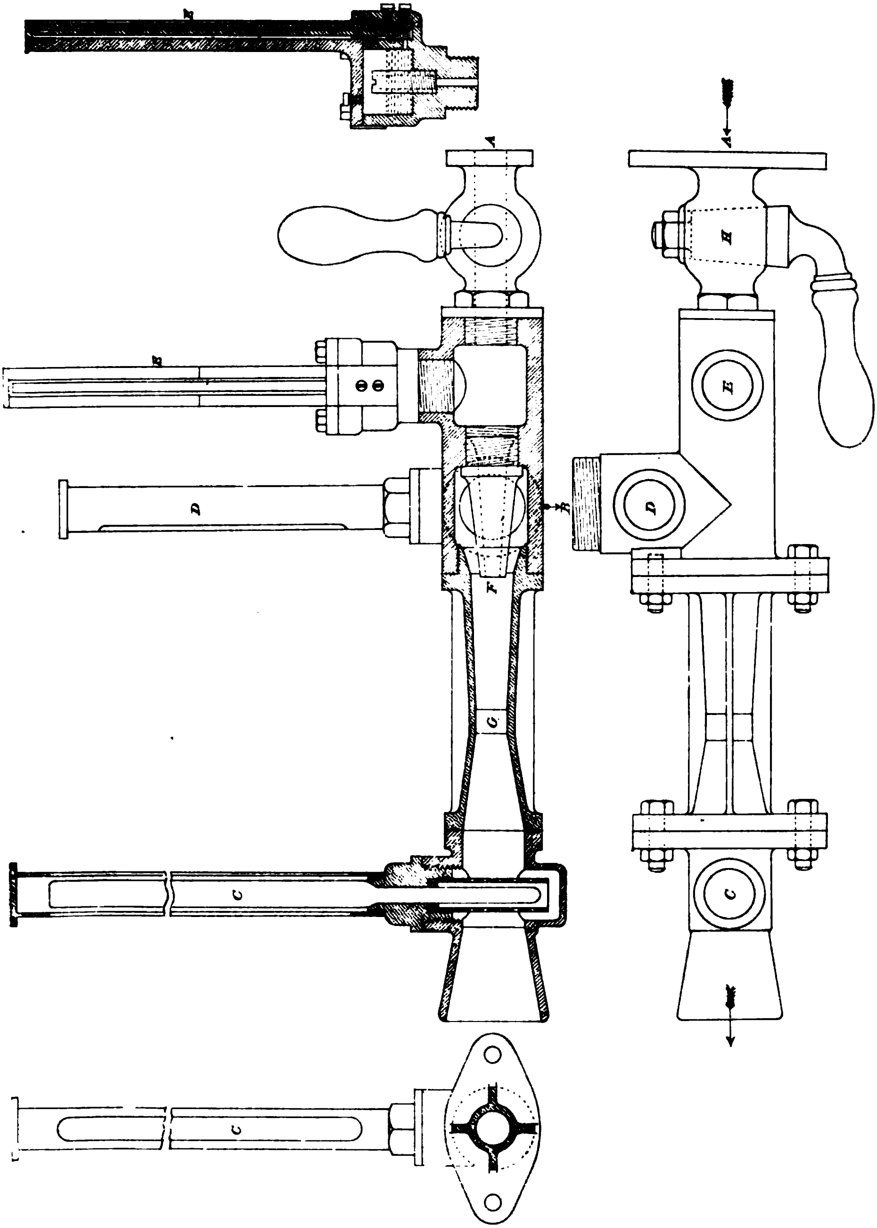
TO ILLUSTRATE MR. AITKEN'S REMARKS.


Pipe to air pump
Chain
Chain
Exhaust Chamber to be lowered over Ladle.
2nd Charge
Original Level of Steel in Ladle
3rd Charge
4th Charge
1st Charge
Time required for four charges - 2 minutes.

Ballantyne, Hanson & Co. Edinburgh & London.

PLATE XIV.

TO ILLUSTRATE MR. A. VON BERGEN'S PAPER.



KRUPP'S PATENT PYROMETER.

Journal of the Iron & Steel Institute

Ballantyne, Hanson & Co Edinburgh & London.

NOTES

ON THE PROGRESS OF THE

HOME AND FOREIGN
IRON AND STEEL INDUSTRIES.

I.—1886.

CONTENTS.

	PAGE
IRON ORES	216
FUEL	238
REFRACTORY MATERIALS	291
PRODUCTION OF PIG IRON	294
PRODUCTION OF MALLEABLE IRON	320
FORGE AND MILL MACHINERY	327
PRODUCTION OF STEEL	331
FURTHER TREATMENT OF IRON AND STEEL	347
PHYSICAL PROPERTIES	352
CHEMICAL PROPERTIES	386
CHEMICAL ANALYSIS	388
STATISTICS	407

IRON ORES.

CONTENTS.

PAGE
I. Occurrence and Composition 216
II. Mechanical Preparation 236
III. Metallurgical Preparation 237

I.—*OCCURRENCE AND COMPOSITION.*

The Formation of Iron Ores.—The object of the investigations undertaken by M. Dieulafait * is to ascertain how far geological facts can be explained by thermo-chemical laws, the inquiry being limited to the formation of minerals at the ordinary temperatures from substances in aqueous solution.

From a consideration of the following reactions,

$2\ FeO + O = Fe_2O_3$, develops 26·6 calories,†
$2\ FeO + 2\ CO_2 = 2\ FeCO_3$, develops 10·0 calories,

it would follow that when oxygen and carbonic anhydride, both in excess, come in contact with minerals containing ferrous and manganous oxide, the latter will be converted into ferric oxide and manganese peroxide, and no carbonate will be formed. If the carbonic anhydride and oxygen come in contact with the minerals slowly, and in quantity insufficient to transform both oxides, the products will be insoluble ferric oxide and soluble manganous carbonate. This explains the formation of manganese minerals comparatively free from iron, from rocks in which iron is present in considerable quantity.

Much more heat is developed when ferrous oxide is converted into ferric oxide than when it is converted into ferrous carbonate; consequently the latter can only be formed in a reducing medium, protected from the action of oxygen. Important deposits of ferrous carbonate exist, and are worked as first-class iron ore. It would therefore seem from this fact, that iron carbonates could not be formed from aqueous solutions, at least under ordinary conditions; but when the mode of association of these ores is investigated, it is seen to be otherwise. From a mineralogical point of view, natural ferrous carbonates may be divided into two groups—spathic iron ore, which is crystallised, and lithoidal ferrous carbonate, which is amorphous. With regard to their age, the differences are not less distinct: ferrous carbonates exist in the gneiss and in sedimentary beds of relatively recent age. The formation of ferrous carbonate of carboniferous age is strictly in accordance with the laws of thermo-chemistry. The coal-measures are of estuarine origin, and consequently the ferrous carbonate has been formed in a reducing medium, rich in carbonic anhydride. The same explanation applies to the numerous lithoidal iron carbonates which exist in sedimentary strata. When the conditions of their formation are investigated, it is at once seen that they were deposited in a reducing medium.

---

* *Comptes rendus de l'Académie des Sciences*, vol. ci., pp. 609–612, 644–646.

† 1 calorie or French unit is equal to 3·968 English units.

The iron in alluvial formations is invariably present as hydrated ferric oxide, which is generally supposed to have been brought up by water from the underlying rocks. If this explanation were correct, crystallised ferrous carbonate would be deposited in the caverns and fissures in these rocks, but, as a matter of fact, all the iron they contain is in the state of hydrated peroxide. This would indicate that the iron has really been derived from water percolating from above.

The Iron Ores of the English Secondary Rocks.—Mr. J. D. Kendall * describes the two main areas in which the ores are found—one forming an irregular band, extending from the sea-coast on the north of Yorkshire to that on the south of Dorsetshire; and the other, which is much smaller, occurring in the counties of Hampshire, Surrey, Sussex, and Kent. Although famous as an ironmaking district upwards of two hundred years ago, this latter area has not for more than fifty years produced any iron ore, for the simple reason that it is too far from the coalfields. In its days of prosperity there was plenty of timber from which the charcoal could be made. Thirty years ago the bulk of the ore used in British iron manufacture was obtained from the carboniferous rocks, and only about 10 per cent. came from secondary rocks. Now, about 56 per cent. of the output comes from these rocks.

Analyses of Iron Ores.—Dr. E. Prziwoznik † publishes the following analyses of iron ores made in the Royal and Imperial Assay Office of Vienna in 1885:—

---

* *Transactions of the North of England Institute of Mining Engineers*, vol. xxxv.

† *Berg- und Hüttenmännisches Jahrbuch der k. k. Bergakademien*, vol. xxxiv. pp. 52–55.

	No. 1.	No. 2.	No. 3.
Ferrous oxide	46·80	5·40	27·26
Ferric oxide	10·10	38·21	33·65
Cupric oxide	...	0·01	0·12
Manganous oxide	2·77	2·31	1·97 (Mn_2O_3)
Alumina	...	2·49	0·20
Lime	1·42	1·17	0·65
Magnesia	3·96	1·31	5·55
Potash and soda	trace	...	...
Silica	1·10	37·65	2·60
Sulphuric anhydride	0·31	0·34	0·41
Phosphoric anhydride	trace	trace	0·02
Carbonic anhydride	32·40	5·40	23·40
Antimonic anhydride	...	...	0·04
Water	1·40	5·50	4·70
Totals	100·26	99·79	100·57
Iron	43·47	30·95	44·75
Manganese	2·14	1·61	1·42
Sulphur	0·12	0·01	0·16
Phosphorus	trace	0·13	0·01

No. 1, Spathic iron ore from the Bistro mine, smelted at Count Andrassy's iron-works in Hungary; No. 2, iron ore smelted at the same works; No. 3, spathic iron ore, with brown hæmatite, also smelted at the same works.

The Vashegy-Rákos Iron Mines.*—The iron mines belonging to the Rimamurány-Salgótarján Company, in Rákos (Gömör County, Hungary), cover an area of 245 acres. Devonian clay-slate forms the roof and floor of the brown hæmatite which occurs in great thickness at Vashegy. The beds strike in a south-east direction, with a dip of 20° to 60°. At Vashegy three ore-beds are to be distinguished. The lowest bed, 39 feet 4 inches thick, contains black, metallic-looking brown hæmatite with 15 per cent. of manganese and 40 per cent. of iron. The middle bed, 65 feet in thickness, is formed of light brown quartzose hæmatite with 2 per cent. of manganese and 50 per cent. of iron. The upper bed, 98 feet in thickness, is composed of a reddish-brown hæmatite with 2 to 4 per cent. of manganese and 35 to 60 per cent. of iron. These beds have been explored for a distance of 6200 feet, and for a depth of 980 feet.

In the Rákos district two beds occur, running parallel to those at Vashegy, and separated from one another by 10 to 20 yards of clay. The lower bed is 26 feet, and the upper one 78 feet in thickness. Both contain brown hæmatite, which passes, in places, into spathic iron ore, red hæmatite, and specular iron ore. The average percentage of iron varies from 40 to 45. The beds have been explored for a length of 2620 feet, and a depth of 430 feet.

---

* *Berg- und Hüttenmännische Zeitung*, vol. xlv. pp. 61–62.

Both mines are worked principally by means of adit-levels, the ore being brought out in one-ton trucks by horses. From the Vashegy mine the ore is taken by means of a wire ropeway to the new blast-furnace at Likér.

Chemical analyses of the Rákos ores gave the following average:—

Fe_2O_3.	MnO.	Quartz.	Al_2O_3.	CuO.	CaO.	P_2O_5.	H_2O.
58·51	4·05	27·68	1·34	0·71	0·032	0·319	7·32

Iron Ore in Bulgaria.—Reporting on the mineral resources of Bulgaria, M. Léon Thonard * states that magnetic iron ore sand is found near Samakof, in the alluvium of the rivers descending from the Vitosch and the neighbouring heights. The sand is formed from the decomposition of the syenite that constitutes the mountain mass. The ore is pure and rich, and has from time immemorial been employed for making iron by a modified Catalan process. The ore is collected in natural or artificial basins, and washed with more or less care. Formerly there was a large number of dressing floors along the flanks of Vitosch and the adjacent mountains, and the peasants collected a total quantity of about 20,000 tons of sand, containing 60 to 70 per cent. of iron.

The ore, the supply of which varies with the quantity of snow which falls in winter, is treated with charcoal in very low furnaces for the direct extraction of the metal. This is transported to forges, where it is hammered and shaped into irregular bars by means of hammers worked by water-power. By this primitive process the waste is enormous, six parts of ore being required to produce one of iron. Round the furnaces and the hammers large heaps of slag have accumulated, and these contain 40 per cent. of iron. The metal is of good quality and easy to work. It was sold not only in the country, but was also exported into Asia. All the trade was concentrated at Tatar Bazardjik, a small town in Roumelia, to the east of Samakof.

Iron-smelting was practised in a large number of small works scattered along the Isker or its tributaries, in the neighbourhood of Samakof, where there were more than 80 furnaces and 18 hammers, and at Etropole, where the Samakof ore was also treated, on account of the abundant supply of wood. The industry flourished for a number of years. The production at that time might be estimated at 3000 tons of metal annually. At the present time, notwithstanding the quality of the product, the industry is rapidly declining in consequence of foreign competition, foreign iron being sold at a lower price than that for which it can be made at Samakof. The ore sells for 8 to 10 francs per ton; the cost price of the iron is from 320 to 500 francs per ton at the works; and the selling price is from 350 to 470 francs.

---

* *Revue universelle des mines*, vol. xix. pp. 1–22.

Deposits of iron ore have been shown to exist in many localities in Bulgaria, notably in the neighbourhood of Teteven and Etropole. Near the frontier, in the mountains south of Trojan, occurs a deposit in a district thickly wooded, but difficult of access. The deposit, which is known in an east and west direction for a considerable distance, is a vein of specular iron ore and red hæmatite in limestone, probably of Liassic age. Its width varies from 1 foot 8 inches to 4 feet. The ore is of good quality and contains 65 per cent. of iron. The deposit was worked at an early period, as is indicated by the slag-heaps. All record has, however, been lost.

The Age of the Hohenkirchen Iron Ores.—A. von Koenen [*] shows that, immediately above the rich manganiferous iron ores of Hohenkirchen, near Cassel, is deposited true Middle Oligocene clay, with *Leda Deshayesiana.* The deposit is consequently much older than the sandy iron ores of Lauge Massen with fossils of Upper Oligocene age, hitherto correlated with it. It may therefore be sought for at those places where the Middle Oligocene clay crops out, considerably below the marine Upper Oligocene and the thick quartz sand succeeding it.

In consequence of the publication of this memoir, concessions have been granted for working iron ore in the neighbourhood of Harleshausen.

The Minerals of the Province of Guipúzcoa, Spain.—The deposits of iron ore in Guipúzcoa are far more abundant than those of other minerals, and were they not so close to those of Biscaya, would be of very considerable importance.

The deposits vary considerably in character; sometimes they are contact deposits between granite and palæozoic rocks, and at other times they are in the form of lodes adjoining these rocks; others occur in the Cretaceous rocks, and some appear to be closely related to ophite.

The following is an analysis of the ore occurring in a lode in palæozoic rock at Miazure :—

Iron.	Manganese.	Magnesium.	Silica.	Oxygen.	Loss on Ignition.	Total.
38·10	3·11	1·40	7·05	15·49	34·83	99·98

Deposits of lignite are found at several places in the province.[†]

Analysis of Swedish Iron Ores.—A. Tamm [‡] publishes analyses of all the principal Swedish iron ores. The results are given in the following table :—

---

[*] *Jahrbuch für Mineralogie*, 1886, vol. i. pp. 93–94.

[†] *Revista Minera y Metalúrgica*, vol. xxxvii. p. 27.

[‡] *Jern-kontorets Annaler*, vol. xli. p. 127.

No.	Fe_2O_3.	Fe_3O_4.	FeO.	MnO.	MgO.	CaO.	Al_2O_3.	SiO_2.	P_2O_5.	S.	Cu.	Loss on Ignition.	Totals.
1.	4·86	73·75	...	0·49	6·05	2·10	2·54	7·60	0·009	0·006	trace	1·90	99·305
2.	...	68·15	1·99	0·53	3·39	4·80	3·52	15·70	0·057	0·037	0·005	0·80	98·979
3.	3·14	59·65	...	0·77	6·80	5·20	trace	23·40	0·025	0·060	0·010	0·60	99·655
4.	11·00	64·22	...	0·16	2·74	1·60	2·00	16·06	0·017	0·305	0·005	2·30	100·407
5.	...	74·15	0·13	1·16	2·05	8·90	1·16	5·44	0·030	0·022	trace	8·00	101·042
6.	...	43·70	0·58	2·40	2·34	25·80	1·64	1·86	0·024	0·077	0·005	20·60	99·021
7.	1·14	76·23	...	0·31	2·85	4·90	1·84	11·90	0·011	0·067	trace	...	99·248
8.	...	65·18	1·03	2·42	2·52	10·30	2·08	12·90	0·022	0·028	trace	5·00	101·480
9.	...	47·23	2·96	8·43	6·27	11·20	0·70	4·80	0·020	0·011	trace	18·30	99·921
10.	...	70·43	0·13	0·26	7·10	4·40	0·64	15·80	0·013	0·059	trace	...	98·832
11.	5·49	67·61	...	0·20	2·60	6·50	2·80	15·00	0·026	0·015	trace	...	100·241
12.	2·57	64·63	...	0·15	6·48	6·90	trace	18·00	0·015	0·002	trace	0·50	99·247
13.	1·14	81·20	...	0·15	1·15	3·24	1.38	10·00	0·016	0·003	trace	0·30	98·579
14.	3·14	66·28	...	0·26	4·07	7·24	1·62	16·70	0·024	0·045	trace	0·40	99·779
15.	34·00	33·97	...	0·52	0·47	3·56	0·26	27·06	0·086	0·015	trace	...	99·941
16.	...	45·98	8·10	13·32	3·39	7·60	1·20	7·80	0·021	0·074	trace	11·80	99·285
17.	...	83·90	0·32	0·15	2·45	3·30	0·84	8·96	0·011	0·022	trace	...	99·953
18.	...	62·55	1·54	0·20	7·24	7·80	1·00	19·34	0·009	0·033	trace	...	99·712
19.	51·43	19·88	...	0·15	0·83	2·60	2·82	20·90	0·043	trace	trace	...	98·653
20.	1·20	60·16	...	0·23	6·40	5·16	2·96	24·10	0·011	0·027	trace	...	100·248
21.	...	75·82	0·51	0·13	5·78	2·36	2·16	13·20	0·015	trace	trace	...	99·975
22.	...	74·57	...	0·13	6·06	2·90	0·82	15·74	0·021	0·004	trace	...	100·245
23.	67·14	5·80	...	0·32	0·22	1·10	0·20	24·00	0·043	0·003	trace	1·00	99·826
24.	3·00	53·45	...	0·18	9·03	6·80	1·20	25·56	0·016	0·015	trace	0·70	99·951
25.	16·43	48·05	...	0·13	2·23	1·90	0·52	28·00	0·039	trace	trace	1·00	98·299
26.	...	79·66	0·40	0·18	2·88	5·74	0·50	10·50	0·017	0·018	trace	0·30	100·195
27.	3·57	63·80	...	0·23	5·26	8·60	0·16	18·60	0·009	0·043	trace	...	100·272
28.	2·57	59·65	...	0·26	6·49	8·90	1·26	21·00	0·015	0·037	0·005	...	100·187
29.	67·14	6·63	...	0·30	1·01	1·90	1·40	22·14	0·060	0·005	trace	...	100·585
30.	...	71·25	0·51	0·26	6·56	4·10	0·26	16·80	0·022	0·008	trace	...	99·770
31.	35·71	33·15	...	0·15	0·43	6·20	0·50	21·80	0·061	0·008	trace	...	98·009
32.	40·43	26·52	...	0·15	0·58	4·60	2·46	25·64	0·065	0·008	0·010	...	100·463
33.	21·71	56·75	...	0·15	trace	0·90	trace	20·55	0·034	trace	trace	...	100·094
34.	27·43	48·89	...	0·08	1·58	1·26	0·96	18·62	0.063	trace	trace	...	98·883
35.	...	65·45	2·31	3·95	6·01	3·40	1·60	10·20	0·007	0·350	0·040	6·70	100·017
36.	...	61·73	4·50	6·62	4·86	4·60	1·86	3·00	0·006	0·118	0·020	12·20	99·514
37.	...	66·79	6·99	6·58	2·30	5·04	trace	1·50	0·007	0·055	0·015	12·00	101·277
38.	...	62·77	7·26	6·58	5·00	1·90	1·88	0·70	0·006	0·040	0·005	14·00	100·141
39.	...	33·55	7·60	5·08	9·14	12·90	1·00	3·20	0·007	0·102	0·070	26·20	98·849
40.	...	49·85	7·33	5·47	6·67	7·20	1·56	2·50	0·004	0·034	0·010	18·40	99·028
41.	...	34·60	8·04	4·95	8·93	14·00	1·96	2·60	0·004	0·012	0·005	25·30	100·401
42.	...	52·20	5·40	5·94	6·20	6·60	1·44	3·90	0·007	0·026	0·005	17·70	99·418
43.	...	36·25	3·42	5·10	8·32	14·40	1·66	7·00	0·007	0·032	0·010	23·70	99·899
44.	...	56·75	5·28	6·40	5·80	4·90	1·92	3·90	0·006	0·022	0·005	14·50	99·483
45.	...	72·71	7·05	7·38	1·15	1·20	1·58	3·90	0·006	0·019	trace	6·00	100·995
46.	80·30	...	...	6·48	1·04	1·40	2·30	5·00	0·007	trace	trace	4·50	101·027
47.	74·71	2·90	...	7·38	1·55	1·40	2·00	5·60	0·007	0·016	trace	5·70	101·263
48.	...	48·27	6·88	4·95	7·92	8·66	0·62	3·24	0·006	0·247	0·070	19·90	100·763
49.	...	49·50	7·26	4·80	7·71	7·30	1·48	4·06	0·007	0·133	0·050	18·40	100·700
50.	...	54·69	7·66	5·06	5·76	5·10	1·78	4·80	0·007	0·171	0·010	14·50	99·438
51.	...	60·27	5·09	6·52	4·86	4·00	1·02	3·90	0·009	0·040	0·010	13·00	98·719
52.	...	54·90	5·34	5·47	6·90	4·76	1·76	6·16	0·004	0·036	0·010	14·40	99·740
53.	...	64·22	4·15	6·50	4·04	4·50	trace	4.84	0·013	0·158	0·040	10·70	99·161
54.	39·29	33·97	...	0·54	0·96	1·90	0·50	22·90	0·009	0·016	0·005	...	100·090
55.	47·14	15·75	...	0·54	0·54	2·00	0·40	32·50	0·011	0·003	trace	...	98·884
56.	0·29	84·52	...	0·23	1·74	3·50	1·66	6·24	0·007	0·105	trace	1·00	99·292
57.	...	72·30	0·32	0·10	6·85	0·50	2·86	15·80	0·020	0·012	trace	1·20	99·962
58.	...	78·92	1·09	0·15	5·80	0·70	1·26	10·94	0·019	0·033	trace	...	98·912
59.	...	78·30	1·88	0·08	3·49	1·20	0·58	13·50	0·015	0·008	trace	...	99·053
60.	...	76·65	0·31	0·50	2·99	2·70	1·34	14·68	0·007	0·027	trace	...	99·204
61.	...	65·45	1·40	0·13	6·20	0·90	1·14	21·10	0·024	1·610	0·040	2·00	99·994
62.	...	65·79	2·13	0·10	11·17	2·90	trace	15·70	0·007	0·066	trace	1·60	99·463
63.	...	87·83	0·13	0·31	1·31	2·80	2·20	3·54	1·550	trace	trace	...	99·670
64.	...	63·67	5·52	2·53	3·06	11·26	trace	7·06	0·011	0·028	trace	6·80	99·939

No.	Fe_2O_3.	Fe_3O_4.	FeO.	MnO.	MgO.	CaO.	Al_2O_3.	SiO_2.	P_2O_5.	S.	Cu.	Loss on Ignition.	Totals.
65.	2·40	72·25	...	0·13	4·61	1·90	2·00	14·50	0·043	0·007	trace	1·00	98·840
66.	...	62·55	1·93	3·04	5·62	8·70	0·08	6·70	0·013	0·141	trace	10·00	98·774
67.	38·29	34·80	...	0·08	1·22	0·70	0·08	23·90	0·037	trace	trace	...	99·107
68.	32·89	35·05	...	0·17	1·78	3·24	1·16	24·20	0·054	0·007	trace	...	98·551
69.	24·71	48·46	...	0·19	2·41	2·80	0·44	18·90	0·045	0·007	trace	...	97·962
70.	...	75·95	...	1·03	2·74	9·00	trace	4·20	0·006	0·338	0·020	5·20	98·484
71.	...	62·26	4·00	7·36	3·10	4·80	2·24	13·34	0·037	0·104	trace	3·00	100·241
72.	2·86	78·72	...	0·08	1·74	4·14	1·68	8·30	0·013	trace	trace	2·20	99·733
73.	...	71·88	0·84	0·15	1·44	4·70	2·84	16·80	0·035	0·100	0·005	0·90	99·690
74.	...	74·57	...	0·15	3·85	5·60	1·56	13·20	0·034	0·030	trace	0·50	99·494
75.	...	67·95	0·90	0·13	7·39	4·10	2·28	13·70	0·036	0·004	trace	2·70	99·190
76.	...	72·01	0·72	0·08	1·33	5·40	1·60	15·56	0·037	0·025	trace	2·20	98·962
77.	...	60·90	0·90	0·10	5·05	14·70	trace	5·60	0·011	0·055	0·005	12·00	99·321
78.	39·54	34·97	...	0·08	0·36	11·50	0·54	3·86	0·034	0·176	trace	8·40	99·460
79.	67·71	10·77	...	0·18	0·50	0·60	1·50	18·56	0·022	trace	trace	...	99·842
80.	37·43	41·43	...	0·23	5·04	4·10	1·62	10·40	0·127	trace	trace	...	100·377
81.	70·57	14·09	...	0·20	4·32	2·60	trace	8·36	0·108	0·012	trace	...	100·260
82.	51·14	24·03	...	0·16	6·70	2·50	1·70	12·40	0·112	0·006	trace	...	98·748
83.	17·43	67·12	...	0·20	3·64	2·10	trace	8·40	0·086	trace	trace	...	98·976
84.	70·14	13·67	...	0·10	4·03	1·80	0·20	8·90	0·093	trace	trace	...	98·933
85.	60·29	15·75	...	0·13	6·12	2·30	2·40	12·40	0·099	trace	trace	...	99·489
86.	12·43	71·25	...	0·11	3·35	0·60	1·86	9·20	...	0·010	trace	...	98·810
87.	25·14	62·97	...	0·19	2·95	0·86	1·32	5·70	...	0·010	trace	...	99·140
88.	69·63	14·17	...	0·08	0·03	1·60	1·80	11·40	0·034	0·012	trace	...	98·756
89.	54·87	18·76	...	0·08	trace	0·54	0·40	24·70	0·030	0·022	trace	...	99·402
90.	0·71	77·05	...	0·26	7·20	1·90	1·82	8·20	0·017	0·030	trace	1·20	98·387
91.	5·29	50·55	...	0·70	4·90	9·80	1·50	26·30	0·022	trace	trace	0·50	99·562
92.	...	60·90	5·91	3·07	6·44	6·40	1·60	8·26	0·084	0·203	As. 0·84	6·00	99·207
93.	...	77·33	...	0·20	5·77	2·20	3·74	10·20	0·006	0·060	trace	...	99·506
94.	...	71·05	0·32	0·15	6·88	3·50	2·94	13·90	0·026	0·027	trace	0·90	99·693
95.	0·86	81·20	...	0·23	5·30	1·70	2·20	7·64	0·017	0·025	trace	...	99·172
96.	5·14	58·00	...	0·18	3·82	9·20	3·04	18·30	0·007	0·005	trace	1·20	98·892
97.	...	80·87	0·31	0·14	6·48	1·74	2·04	5·66	0·007	0·010	trace	1·40	98·657

The ores analysed were from the following localities :—

Province of Gefleborg :—Thorsaker parish, 1. Myggbo mine, 2. Stoll mine, 3. Örbäck mine.

Province of Upsala :—Rasbo Kil parish, 4. Carolina mine; Alunda parish, 5. Hammarin mine, ore No. 1, 6. Hammarin mine, ore No. 3.

Provice of Kopparberg :—Sundborn parish, 7. Hornberg mine; Tuna parish, 8. Plat mine; Garpenberg parish, 9. Erik mine, 10. Kompani mine; Folkärne parish, 11. Tvär mine, 12. Wilhelmina mine, 13. Anna mine; Silfberg parish, 14. Bräfall; Ludvika parish, 15. Sultin mine, 16. Knip mine, 17. Hätt mine; Norrbärke parish, 18. Flogberg mine.

Province of Vestmanland :—Norberg parish, 19. Holm mine, 20, 21, 22. Kallmora mine, 23. Torf mine, 24. Afzelii mine, 25. Ny mine, 26, 27. Ås mine, 28. Morgon mine, 29. Riddar mine, 30. Smörberg mine, 31, 32. Risberg, 33. Förening mine, 34. Mellan mine, 35, 36. Gröndal, 37, 38. Johannisberg, 39, 40, 41. Stor mine, 42, 43, 44, 45, 46, 47. Granrot, 48, 49. Solskensberg mine, 50, 51, 52. Gamla, 53. Lar mine; Vestanfor parish, 54, 55. Stortägt mine, 56. Matt mine, 57. Johanna mine, 58. Högberg mine; Skinnskatteberg parish, 59. Östra Stripa mine, 60. Hagg mine, 61. Alice mine, 62. Sell mine.

Province of Örebro :—Nya Kopparberg parish, 63. Björk mine, 64. Mixed ores from Svartrik, 65. Moss mine, 66. Gezelii mine; Ramsberg parish, 67. Läng mine; Lind parish, 68. Ingel mine, 69. Kärr mine, 70. Kampa mine; Grythytte parish, 71. Brunsjög mine; Hjulsjö parish, 72, 73. Gunnarsberg mine, 74. Gröndal mine, 75. Ösjöberg mine, 76. Norr mine; Jernboå parish, 77. Hagg mine; Nora parish, 78. Calcareous hæmatite from Striberg, 79. Vret mine, 80 to 87. Dalkarlsberg, 88. Gammel mine, 89. Stor mine, 90. Gamla Hvilar mine, 91. Sjö mine, Vinteräsa mine, 92. Sanna.

Province of Vermland :—Kroppa parish, 93. Mellan mine, 94, 95. Norra Sund mine, 96. Stenå mine.

Province of Södermanland :—Sköldinge parish, 97. Oscar mine.

Norwegian Iron Ore Deposits.—In Norway contact deposits of iron ore occur, according to J. H. L. Vogt,* where Silurian strata are penetrated by granite and syenites. The two principal localities are, the Skreia iron ore field, north-west of Christiania, and the district south-west of Drammen. The former is an island-like patch of Silurian strata, 4·2 miles long and 0·6 to 1·2 miles wide, surrounded by granite. The prevailing ore of both districts is magnetite, iron glance being of rarer occurrence. The ores occur either immediately at the junction of the granite and Silurian beds, or in the metamorphic beds nearest to the granite, and form small beds or fahlband-like impregnations. In places they traverse the strata in the form of small veins.

The work is illustrated by a number of plans and sections. Technically, these contact deposits are not of great importance. The mines, worked in former times, are now all abandoned.

Analyses of Iron Ores.—The following analyses are by Mr. J. Cuthbert Welch †:—

Hæmatites.

	No. 1.	No. 2.	No. 3.	No. 4.
	Per cent.	Per cent.	Per cent.	Per cent.
Ferric oxide	98·972	93·428	86·000	95·714
Manganous oxide	...	trace	...	0·062
Lime	trace	0·426	0·647	0·833
Magnesia	...	0·008	trace	0·162
Alumina	...	0·326	trace	...
Silica	0·206	3·272	9·352	1·606
Phosphoric anhydride	0·037	...	1·556	0·461
Titanic anhydride	...	...	trace	...
Arsenic	trace	0·115	...	0·235
Lead	...	...	0·376	trace
Copper	trace	trace	0·138	...
Sulphur	0·320	0·036	0·744	trace
Combined water	...	0·520	0·064	...
Hygroscopic water	0·326	1·316	0·726	0·276
Totals	99·861	99·447	99·603	99·349

No. 1 was a stalactitic compact specimen from Arendal in Norway, with a mean density of 5·260. No. 2 was from Penrhyn, North Wales; its density was 4·536. No. 3 was from Ulverstone, Cumberland; its density was 4·508. No. 4 was from Huel Just, Cornwall; its density was 4·915.

---

* *Norske ertsforekomster*, Christiania, 1885, p. 130.

† *Chemical News*, vol. liii. pp. 52–53, 65–67, 79–80.

Limonites.

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Ferric oxide	82·120	81·720	83·428	84·285	82·714
Ferrous oxide	...	...	trace	...	...
Manganous oxide . . .	...	0·012	trace	...	...
Lime	...	0·346	0·172	0·407	1·014
Magnesia	0·078	0·153	...	...	0·348
Alumina	...	0·208	trace	...	0·522
Silica	0·496	1·522	0·732	0·284	0·416
Phosphoric anhydride . .	0·013	...	0·034	...	0·053
Arsenic	0·126	...	...	...	0·097
Lead	...	...	0·053	...	...
Cupric oxide	...	...	...	...	0·062
Sulphur	0·252	0·074	0·305	...	0·208
Combined water	14·512	14·396	14·970	14·534	13·626
Hygroscopic water . . .	2·156	1·130	0·090	0·216	0·634
Totals . . .	99·753	99·561	99·784	99·726	99·694

No. 1 was from Weardale, Durham; its density was 3·412. No. 2 was a botryoidal mass from Salisbury, Connecticut, United States; its density was 3·524. No. 3 was a stalactitic specimen from Restormel, Cornwall; its density was 3·948. No. 4 was the inner portion of a crystal, a pseudomorph after calcite from Siegen, Saxony; its density was 3·925. No. 5 is an analysis of the whole of the crystal, the analysis of the centre of which is given in No. 4.

Göthite.

	No. 1.	No. 2.
	Per cent.	Per cent.
Ferric oxide	86·142	86·172
Manganous oxide	...	0·339
Lime	0·210	0·072
Magnesia	...	0·016
Alumina	0·326	0·760
Silica	0·520	0·816
Phosphoric anhydride	0·032	...
Arsenic	...	0·208
Cupric oxide	0·714	...
Combined water	11·846	11·414
Totals	99·790	99·797*

No. 1 was from St. Gothard, Switzerland; its density was 4·223. No. 2 was from Tincroft, Cornwall; its density was 4·324.

---

* 99·865 in original.

The Iron Ores of India.—C. R. von Schwarz,* superintendent of the Government ironworks in India, describes in detail the different iron ore deposits.

Iron ore occurs in nearly all the districts of India, the varieties most frequently met with being red and brown hæmatites and magnetite, the latter occurring partly as the titaniferous iron sand which forms the material principally used by the natives in the production of "Wootz" steel. Spathic iron ore, clay iron ore, chrome iron ore, and blackband occur more rarely.

Important lodes of brown hæmatite and magnetite occur frequently in faults in metamorphic and sub-metamorphic rocks. The richest red hæmatites of Central India are generally found in the lower beds of transition rocks. Iron ore occurs nearly everywhere in the great Vindhyan formation of India, but in all cases in which the ore is in sufficient quantities to prove workable it occurs in lodes and not in beds.

In former times the natives produced iron in nearly all parts of India, and the author is of opinion that the inhabitants of India were acquainted with the process at a much earlier date than Europeans. The iron and steel produced by the natives is usually of a very high quality.

The most important iron ore fields of India are the following:—

1. The brown hæmatites of Barrakur, in Bengal.
2. The magnetites and specular ores of Chanda, in the Central Provinces.
3. The red and brown hæmatites of Kutni, in the Central Provinces.

1. *The Brown Iron Ores of Barrakur, Bengal,* cover an area of 25 square miles, and, on an average, are 400 feet thick. They occur on the surface, and may be mined at a cost of eight annas (9d.) per ton.

The following is their mean composition—

	Per Cent.
Ferric hydrate ($2Fe_2O_3, 3H_2O$)	78·1
Manganous oxide	2·6
Carbonates of lime and magnesia	2·1
Alumina	5·1
Silica and silicates	9·2
Phosphoric anhydride	1·4
Water	1·5
Total	100·0

---

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen,* vol. xxxiii. pp. 715–717, 734–736, 751–754, 771–774.

Coal occurs in the immediate neighbourhood of the ore, and its composition is as follows :—

Fixed Carbon.	Volatile Combustible Constituents.	Volatile Non-combustible Constituents.	Ash.	Total.
65·0	20·0	3·5	11·5	100·0

The coal occurs in beds of from 4 to 60 feet in thickness, and is worked partly by adits, partly by shafts. The quantity available is about 800 million tons.

At a distance of 10 miles from the iron ore, limestone of the following composition is found :—

Calcium Carbonate.	Alkalies.	Ferric Oxide and Alumina.	Silica and Silicates.	Total.
71·0	12·0	3·0	14.0	100·0

Dolomite containing 28 per cent. of magnesium carbonate is found within 9 miles of the iron ore, and fireclay of fairly good quality occurs within 20 miles.

In 1881 the Government established ironworks at Barrakur, in the immediate neighbourhood of the ore and coal. It is the only one in India, and it consists of two blast furnaces and a foundry, and produces at present 45 tons of finished products per day. The works employ 5 Europeans and 1500 natives, who, although less robust than European workmen, are very easy to manage if treated in a proper manner. A common workman is paid at the rate of 2½ annas (about 2¾d. present value) a day, and a woman 1½ anna. A native working at the blast furnace receives from 4 to 8 annas (4½d. to 9d.) per 12 hours shift.

The following are the prices of the raw materials delivered at the works :—

	Per Ton. s.	d.
Iron ore	1	2
Coal	4	6
Coke	12	0
Limestone	6	9

2. *The Magnetites and Specular Iron Ores of the Central Provinces.*—The following are analyses of specimens of ores from Chanda :—

	Magnetite. Per cent.	Specular Ore. Per cent.
Ferric oxide	95·5	98·0
Ferrous oxide		...
Manganous oxide	...	trace
Calcium carbonate	0·5	0·5
Alumina	...	0·5
Silica and silicates	4·0	0·75
Sulphur	...	trace
Totals	100·0	99·75

The specular iron ore deposit at Loharas forms a hill about three-fourths of a mile long, half a mile broad, and 150 feet in height above the surrounding ground. The magnetite deposit at Pipalgaon occurs in a similar manner, and the quantity of ore which can be worked open-cast is about 30 million tons.

There are other deposits of specular iron and magnetite of minor importance elsewhere, and at Ratnapur there is a brown hæmatite lode 40 feet thick, the ore containing 50 per cent. of iron. At Dewalgaon there is a hill 250 feet high composed of brown hæmatite.

The forests of the Chanda district cover 3325 square miles, and it is calculated that, if properly managed, they can give a continuous annual supply of 16,000 tons of dry wood per square mile. It is the intention of the Indian Government to work the Chanda deposit, and the forests have consequently been placed under proper management. The mean weight of the cubic foot of Indian wood is 50 lbs., one-fourth higher than that of the wood used for smelting purposes in Styria and Sweden.

The coal occurring in the Chanda districts is of poorer quality than that found at Barrakur; the following shows the chemical composition:—

Fixed Carbon.	Volatile Combustible Constituents.	Volatile Non-Combustible Constituents.	Ash.	Total.
45·5	26·0	14·0	14·5	100·0

It is estimated that 2·5 billion tons of it may be mined. As may be seen from the composition, the coal does not cake. The Government propose to erect ironworks at Durgapore, on the Erai river, as this place is near both the fuel and the ore.

Fireclay is found in the Warora coal-mines; it has the following composition:—

	Per Cent.
Aluminium silicate	83·0
Ferric oxide	0·5
Calcium carbonate	1·8
Alkalies	2·1
Iron pyrites	1·8
Silica	2·4
Water	4·1
Organic matter	4·1
Total	99·8

Good serpentine is found about 12 miles from the place where it is proposed to build the ironworks.

Manganese ore is found at Ramtek; it contains—

	Per Cent.
Manganese	54·6
Iron	6·5
Oxygen combined with Mn and Fe	26·5
Calcium carbonate	1·2
Silica and silicates	6·0
Water	5·2
Total	100·0

Limestone for flux is found within a distance of 18 miles from Durgapore; its composition is as follows:—

Calcium Carbonate.	Magnesium Carbonate.	Ferric Oxide and Alumina.	Silica and Silcates.	Total.
90·0	5·0	2·5	2·5	100·0

The cost of the raw materials per ton at the works will be:—

	s.	d.
Specular iron ore from Lohara	5	9
Charcoal	10	6
Coal from Warora	5	9
Limestone	4	6
Fireclay	5	9

The wages are even lower in the Chanda district than at Barrakur.

3. *The Red and Brown Hæmatites of Kutni, in the Central Provinces.*

The chief ore is pisolitic limonite, having the following composition:—

Ferric Hydrate ($2Fe_2O_3, 3H_2O$).	Alumina and Calcium Carbonate.	Silica and Silicates.	Phosphoric Auhydride.	Total.
94·6	2·7	1·3	1·4	100·0

The ore covers several square miles, and has a mean thickness of 5·5 feet; the quantity which may be mined by open-cast is estimated at about 50,000,000 tons. The ore-field is 7 miles from Kutni, and is close to railway communication. Manganiferous specular ore and psilomelane (hard manganese ore) occur at Gosulpore, 36 miles from Kutni, and adjoin a railway. The specular ore has a thickness at the surface of 15 feet, and the manganese ore has a similar thickness of 35 feet.

About 30 miles from the main iron ore field are the Umaria coal-fields.* The coal has the following mean composition:—

Fixed Carbon.	Volatile Combustible Constituents.	Volatile Non-combustible Constituents.	Ash.	Total.
55·0	25·0	7·0	13·0	100·0

---

* Compare *Journal of the Iron and Steel Institute*, 1884, p. 664.

The coal exists at a depth of 180 feet from the surface, and has a mean thickness of about 24 feet; about 50,000,000 tons may be won. Limestone, dolomite, and fireclay also occur in considerable quantities near the iron ore.

The following shows the cost of the ton of raw material at the place where it is proposed to erect the ironworks:—

	s.	d.		s.	d.
Iron ore from Bijori	1	6	to	12	0
Charcoal	15	0			
Wood	6	0	to	12	0
Coal from Umaria	7	6			

In calculating the cost of material the rupee has been considered equal to 1s. 6d.

Iron Ore in the Hudson's Bay Territories.—The Hudson's Bay Territories include the whole of the Dominion of Canada east of the Rocky Mountains and north of the watershed of the St. Lawrence. Very little exploration for economic minerals has yet been done in these regions, but already great wealth is indicated in some localities. In discussing the prospective mineral resources of these vast territories, Dr. R. Bell states * that a fine variety of magnetite occurs in large quantites near the entrance of Black Bay, on the north side of Athabasca Lake. A large deposit of finely granular magnetite, with 45·86 per cent. of iron and no titanic acid, occurs on Knee Lake, between Lake Winnipeg and Hudson's Bay. Magnetic iron ore occurs on the north side of Hudson's Strait, and small deposits of it are not uncommon among the Huronian bands in various districts.

Hæmatite is found in bands on Long Island, Hudson's Bay, and a promising deposit of this ore has been opened on Big Black Island, in Lake Winnipeg. On the northern bay of Great Slave Lake is a vein of foliated specular iron ore.

Clay ironstone is found on Melville Island, and small quantities occur in many places in the Cretaceous and Tertiary marls. A large deposit of this ore was discovered by the author at the foot of the Grand Rapid of the Mattagami River.

Probably the most extensive deposit is that of manganiferous spathic iron ore on the Nastapoka Islands, on the east side of Hudson's Bay. The ore occurs as a thick band, divided into layers of a few inches, overlying quartzites and shales. The ore contains on an average 50 per cent. of iron carbonate and 25 per cent. of manganese carbonate. It would thus be a valuable ore for the manufacture of spiegeleisen.

---

* Paper read at the Pittsburg meeting of the American Institute of Mining Engineers, February, 1886. *Transactions*, vol. xiv. pp. 690–698.

Coal of Carboniferous age has been found in workable seams in Bank's Land and the islands of the Melville Archipelago. Lignite is well known to occur extensively in the Cretaceous and Tertiary strata of the North-west Territories, and anthracite is said to occur on Long Island.

Iron Ore Deposit in Ontario.—Mr. E. J. Chapman states * that the iron ore deposit in North Hastings, Ontario, is certainly of enormous extent, but is practically useless from the presence of a considerable amount of titanium in the ore. At the surface the ore contains 8 per cent. of titanic acid. The question arose whether the titanium would diminish at lower depths, or would be found to be permanently present in the ores. No analysis has yet been made of titaniferous magnetite taken from any great depth beneath the surface. It is, therefore, interesting to note that a core of this ore taken by a diamond-drill from a depth of 270 feet showed 10·86 per cent. of titanic acid, equivalent to 6·5 per cent. of titanium. The occurrence of enormous masses of titaniferous ore in the immediate vicinity of large deposits of iron ore perfectly free from titanium is a very curious fact.

Iron Ore in the Central Ontario District.—Mr. T. Hayes gives † the following partial analysis of a magnetite occurring about 4 miles nearly due north of the Blairton :—

	Per Cent.
Ferrous oxide	27·32
Ferric oxide	58·93
Sulphur	0·03
Phosphorus	0·08
Titanium	None.
Metallic iron	62·50

The Steel Ores of the Southern United States.—With one exception, no blast furnace in Virginia can be said to produce a pig iron suitable for the Bessemer process. Throughout the Alleghany ranges, from Maryland to Central Alabama, numerous veins gave promise of furnishing suitable ores, but they have either proved to be too small to be profitably worked, or the ore to be too impure, or want of facilities for communication has rendered it impossible to work them as yet with any success.*

---

* *Journal of the United States Association of Charcoal Ironworkers*, vol. vi. p. 343.

† *Iron Age*, vol. xxxvi. No. 18.

The Cranberry Iron Ore Deposit.—The large deposit of magnetite at Cranberry, North Carolina, is mined by open cast. The belt of ore commences in the north-east of Mitchell County and extends north 75° east for about 15 miles into Carter County, Tennessee. Like all the veins of the Alleghany Mountains, it is lenticular, having large bodies of ore connected by a comparatively narrow vein. These large bodies vary in their distance apart from 0·5 to 2 miles, the vein between being usually 4 to 5 feet thick. The ore outcrops at Cranberry, and lies between hard light-grey gneiss and a darker variety of this rock. The body of ore is frequently capped and intermingled with well-crystallised hornblende and epidote. Pyroxene and calcite are also abundant in the vein, and sometimes a few crystals of quartz are also found. No apatite is found, and phosphorus generally is either totally absent or only present in traces. The ore is self-fluxing, and its composition is shown by the following analyses †:—

	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Magnetic oxide of iron	94·37	91·45	85·59	80·77	91·89
Manganese oxide	0·26	0·06	0·24	1·42	0·32
Lime	0·43	1·01	0·72	...	1·06
Magnesia	0·36	0·53	0·33	...	0·23
Alumina	0·42	0·77	0·11	0·52	1·03
Silica, pyroxene	4·16	5·74	11·48	9·08	4·02
Sulphur	...	...	...	...	0·25
Phosphoric anhydride	...	...	...	...	trace
Water	...	0·44	1·53	...	1·15

The ore is partly smelted and partly sold. It costs less than sixty cents per ton to mine, and can be sold at a very considerable profit. Other similar deposits are known to exist in Watanga and Aste Counties, North Carolina.

Mineral Resources of Louisiana.—The United States Geological Survey has been making an investigation of the mineral resources of Northern Louisiana, which are claimed to be more general and extensive than have yet been reported. Deposits of brown hæmatite were found in Webster, Claiborne, and other parishes. An analysis of Claiborne iron ore by Mr. J. B. Britton gave the following results :—

---

* *Iron Age*, vol. xxxvi. No. 27.

† *Ibid.*, vol. xxxvii. No. 8.

Fe.	O.	MnO.	Al_2O_3.	CaO.	MgO.	SiO_2.	S.	P_2O_5.	H_2O.	Loss.	Total.
42·59	18·23	trace	8·52	trace	0·02	16·98	0·03	2·41	11·14	0·08	100·00

The Cornwall Iron Ore Mines, Pennsylvania.—These magnetite mines are situated five miles south of Lebanon, in three prominent hills (Big, Middle, and Grassy Hills), standing in front of the Mesozoic hill country of Northern Lancaster and Southern Lebanon Counties, and overlooking the great limestone plain to the north. According to Mr. E. V. d'Invilliers,* the extreme length of the uncovered ore deposit is 4400 feet, the total area being 63 acres. The ore mass lies against the south sloping face of a dolerite trap dyke, and follows the irregular course of the trap, which changes several times in a very abrupt manner.

The ore mass is evidently a regularly stratified formation, sloping down to the south-west against the edge of the Mesozoic rocks, and rising to the north-east into the air, where, on the top of Big Hill, it is worn off. The whole deposit exhibits a regular and apparently horizontal stratification. When the stratification is viewed sideways a general dip of the ore-beds towards the south-west is plainly discerned. This dip amounts to 5°. Beds of bluish-white limestone are regularly interstratified with the ore mass.

At the office at the mines six blocks of ore, each intended to be a cubic foot in dimension, have been dressed, in order to show each grade of ore occurring at the mines. After being dressed and weighed, borings were taken from them for analysis. The following table shows their weight and percentage of iron :—

Block.	Weight.	Grade.	Iron.
	lbs.		Per cent.
1.	224	1st	62
2.	257	2nd	57
3.	257	2nd	55
4.	228	3rd	44
5.	231	3rd	42
6.	199	4th	24

This arrangement of grading is a chemical and not a commercial one. The following analyses are arranged in the order of their percentages of metallic iron, to show the chemical composition of the different grades :—

---

* Paper read at the Pittsburg meeting of the American Institute of Mining Engineers, February, 1886.—*Transactions*, vol. xiv. pp. 873 904.

	1	2	3	4	5	6	7
Iron . .	64·900	57·050	51·450	51·050	48·800	46·400	41·900
Manganese .	0·158	0·064	0·072	0·115	0·057	0·238	0·194
Copper . .	0·005	0·447	0·559	0·295	0·599	0·066	0·319
Alumina .	0·324	1·394	1·080	1·289	2·315	7·815	4·970
Lime . .	1·010	2·740	2·600	2·340	4·330	2·550	2·810
Magnesia .	1·131	3·942	6·652	6·616	5·531	2·738	7·459
Sulphur . .	0·071	2·531	2·459	3·271	1·807	0·050	0·428
Phosphorus .	0·014	0·007	0·010	0·010	0·018	0·023	0·019
Silica . .	3·980	8·650	12·270	11·560	12·940	18·040	20·910

1. Sample of 115 pieces of "Nigger-head ore" from Middle Hill; 2. "No. 3 ore" from Middle Hill; 3. Fine or soft ore, "No. 3 ore" from west cut, north side of Middle Hill; 4. The same from south side of Middle Hill; 5. "No. 1 ore" from Middle Hill; 6. Fix or wash ore from Big Hill; 7. "No. 1 light ore" from Middle Hill. The samples were dried at 212°.

All No. 2 and No. 3 ores are roasted. Analyses of roasted Cornwall ore gave the following results :—

	1	2	3
Iron	57·85	56·78	55·35
Silica	9·50	10·70	11·00
Alumina	3·65	4·50	4·21
Lime	2·12	2·40	2·32
Magnesia	3·76	4·13	4·00
Sulphur	0·45	0·40	0·50

Until within recent years the mining of iron ore at Cornwall was carried on under the present system of quarrying stone or loose rock, each individual shareholder in the ore-bank raising ore from his own "mine-hole." This systemless method of mining led to repeated trouble and litigation. In 1852 mining proper began at Cornwall, and the first sale of ore was made.

The commercially prepared ore of course requires sorting into lump and fine ore. Skilled mining labour in the great open cuts does not enter into the question of expense at all, except in so far as the miner is required to judge as to the grade of the ore, where sorting is necessary. The miners work in gangs of 40 men, every gang having its head miner. They are mostly diggers simply,.as no hand-drilling is pursued in the mines. The precision, celerity, and economy of the work are enhanced by the use of compressed-air rock-drills. These, six in number, are of the Ingersoll type, 3½-inch cylinder with hand-feed, and 6½-inch stroke. They make 300 blows a minute, and, boring 3-inch holes, make 150 feet per day of 10 hours.

The holes are usually drilled 5 feet apart and 12 feet deep, the charge of dynamite varying from 5 to 8 lbs. per 12-inch hole. The air-compressor is of the duplex type, with 28-inch steam-cylinders and 21-inch air-cylinders, both having a 48-inch stroke. The receivers furnish air at 60 lbs. pressure, and the farthest point reached in the mines is 1800 feet from the compressor, when there is a loss of 2 lbs. pressure.

In the autumn of 1885, 200 men were employed, and the output was 35,000 to 45,000 tons per month, or an average of 8 tons per man per day, allowing 25 days to the month, with wages of 14 cents per hour. The total cost of mining ore, therefore, at Cornwall can hardly exceed 25 to 30 cents per ton. The total production from this vast deposit from 1740 to January 1, 1886, amounted to 7,327,747 tons; the output during 1885 being 508,864 tons. This output is the demand during an "off-year" in iron. It is the output from only one-third of the power of the present plant, and it is fairly within bounds to say that a yearly output of 2,000,000 tons could be readily managed; and this output could be kept up for at least fifteen years before exhausting the amount of ore above water-level in the three hills.

Iron Ore Deposits of Southern Utah.—One of the most remarkable iron ore districts of the world is found in Iron County, Utah. The ore, according to Mr. W. P. Blake,* outcrops in a low range of hills. The adjoining rocks are limestone, porphyry, and quartzite. The ore-beds are from 10 to 100 feet in thickness, and some of the outcrops extend for 1000 feet. The ore is chiefly magnetite and hæmatite, showing distinct planes of structure parallel with the walls. Cavities lined with octahedral crystals are common, and portions of the ore exhibit magnetism and polarity in a remarkable degree. The weathered surfaces of the ore are generally coated by a lustrous black scale. The associated mineral is chiefly apatite. There are, however, layers of ore of considerable thickness apparently free from apatite.

---

* Paper read at the Pittsburg meeting of the American Institute of Mining Engineers, February, 1886.—*Transactions*, vol. xiv. pp. 809–812.

The following are results of assays of these ores :—

Name of Ore.	Metallic Iron.	Phosphorus.
Armstrong	63·925	0·226
Adams	58·675	0·214
Smith (east side)	59·625	0·032
Smith (west side) . . .	61·425	0·265

The beds are well situated for working. Their extreme distance from water transportation is, of course, a great disadvantage; but for the supply of the central portions of the Rocky Mountain region railway system, it has the advantage over Pennsylvania, Ohio, or Missouri. There is, besides, a considerable market for iron throughout Utah and the adjacent territories.

Geology of the Low Moor Iron Ores.—According to the views hitherto entertained, the principal ore-banks of Low Moor, in Alleghany County, Virginia, belong to the Oriskany sandstone. Mr. B. S. Lyman * finds them to be somewhat different in age. The main ore-bed he identifies with that of the Marcellus shales. This result is of practical importance, since it may, in consequence, be now reasonably expected that the character of the bed, in its origin, persistence, and thickness, will correspond more with the Marcellus ore-bed, so valuable in the Juniata Valley and south-westward towards the Potomac, than with the uncertain poor deposits of brown hæmatite found at places in the same region along the outcrop of the Oriskany, which are evidently the product of leaching from beds of ferruginous rock.

Arkansas Manganese Ore.—The following is the average composition of the ore mined at the southern mine of the Keystone Manganese and Iron Company, Arkansas :—

Metallic Manganese.	Metallic Iron.	Phosphorus.
50·430	3·660	0·164

It is anticipated that it will be possible by washing the ore to raise the percentage of manganese it contains to 55 per cent. †

---

* Paper read at the Pittsburg meeting of the American Institute of Mining Engineers, February, 1886.—*Transactions*, vol. xiv. pp. 801–809.

† *Iron Age*, vol. xxxvii. No. 3.

II.—*MECHANICAL PREPARATION.*

Ore Washer at Copake Ironworks, New York.—The ore washer described by Mr. W. A. Miles* is a modified form of the Bradford washer, and consists of a series of iron staves, properly secured to spiders, forming a cylinder with conical end revolving by means of gearing. The ore to be washed is fed to this cylinder from a shoot which also carries an abundant stream of water. The staves are perforated with small holes, and have on their inner faces a series of cutters to break up clay lumps. The cylinder is immersed in a wooden trough, in which water is maintained at a desired elevation by means of a gate. A large opening in the receiving head permits of feeding wash and lump ore up to 8 inches in diameter. The blades force the ore, as washed, towards the discharge head, where it is lifted by perforated wings into a rinsing chamber. This forms a connection between the washer and the separator.

The separator consists of a series of rings held in a suitable frame, and spaced by means of bolts and thimbles. The ore from the rinsing chamber passes through, and all sizes small enough to pass between the rings drop, while the larger pieces are carried to the end of the separator. The water that is discharged from the wooden trough, carrying fine ore, passes into a revolving screen, which saves all ore which will not pass through a sieve of No. 10 mesh.

At the Copake Ironworks, New York, in a washer and separator of this kind, 20 tons of ore have been prepared per hour from material carrying 20 per cent. of ochre, delivering the washed ore at from $\frac{1}{4}$ inch to $1\frac{1}{2}$ inch diameter, and separating the larger lumps for crushing. The principal dimensions are:—Washer proper, 52 inches in diameter, and 8 feet long; the holes in the staves are $\frac{1}{4}$ inch in diameter. Rinser, 38 inches in diameter, and 20 inches long. Separator, 30 inches in diameter, and 3 feet inside length. Length from trunnion of washer to trunnion of separator, 14 feet.

---

* *Journal of the United States Association of Charcoal Ironworkers*, vol. vii. pp. 6–11, with an illustration on a scale of 1 to 40.

III.—*METALLURGICAL PREPARATION.*

The Davis-Colby Calciner.—This calciner * consists of two circular walls, one within the other. † In the outer wall are built sixteen fire-arches for the ingress of gas and air, and as many working doors to give access to the ore. At the base of the furnace are eight doors for the withdrawal of the roasted ore. Within the kiln is a circular central flue opening directly into the draft-stack, its walls being built of firebrick, and resting on the foundation. Built into the outer wall, and extending around the kiln, is a flue for the admission of gas; the gas passes from this flue into the arches through slots in the brickwork, and, air being admitted, takes fire. The ore occupies the annular space between the outer wall of the kiln and the central flue, the annular space enlarging gradually towards the bottom to provide for the expansion of the heated ore. The products of combustion pass partly up through the ore, but mainly through a series of small flues into the central flue, and thence to the stack. A channel is left in the foundation, through which a man can enter the interior of the kiln and clean the flues should they become obstructed. A bell and hopper are fitted at the top of the kiln, and, with an ore-crusher properly placed, only one man is required per turn to feed a kiln of 60 tons daily capacity.

At the Katahdin Ironworks, Maine, this calciner has, with one year's stoppage, been in constant use during the past six years, treating ore containing 4 per cent. of sulphur; in the roasted material this is reduced to, on an average, 0·07 per cent.

---

* Compare *Journal of the Iron and Steel Institute*, 1885, p. 340.

† *Iron Age*, vol. xxxvii. No. 6.

FUEL.

CONTENTS.

	PAGE		PAGE
I. Calorific Value	238	VI. Natural Gas	263
II. Coal	239	VII. Artificial Gas	267
III. Charcoal	247	VIII. Coal Mining	273
IV. Coke	248	IX. Coal Washing	287
V. Liquid Fuel	262		

I.—*CALORIFIC VALUE.*

Proposed Apparatus for Determining the Heating-Power of Different Fuels.—The first requisite in determining the heating-power of a fuel is proper apparatus, such as has not been used in any of the tests of American coals yet reported. Mr. W. Kent [*] describes an apparatus he has designed for the purpose. Its principal feature is that it is not a steam boiler at all, but only a water-heater. It consists of two sheet-metal cylinders, each 12 feet long, the upper one 4 feet in diameter, the lower one 3 feet, and connected by a short neck at one end only. The upper cylinder is provided with a fire-box 3 feet 6 inches in diameter and 6 feet long, and its rear end is filled with about 100 2-inch tubes. The lower cylinder is completely filled with 2-inch tubes. The fire-box is lined with firebrick, and contains a grate surface 2 feet by 2½ feet. A hanging bridge-wall of firebrick is placed in the upper part of the fire-box in the rear of the bridge-wall proper, for the purpose of insuring complete combustion. The gases of combustion pass through the tubes of the upper heater, then down through a firebrick connection into the tubes in the lower heater, finally passing into the chimney. Air is fed to the fire from a fan-blower; the air being measured by recording the revolutions of the fan, checked by an anemometer in the air-pipe. Its weight should be calculated from the barometric pressure, the moisture in it determined, and its temperature taken before it enters the ash-pit. The temperature of the escaping gases should be taken by several thermometers in different portions of the chimney connection. Cold water, of known temperature, is supplied to the bottom of the lower heater. The water passes through the two heaters in an opposite direction to that of the gases of combustion, and escapes at the top of the upper heater by an outlet pipe to two measuring tanks, which are alternately filled and emptied, the temperature of the out-flowing water being taken. The rate of flow of water through the apparatus is regulated so that the temperature of the out-flowing water does not exceed 200° F. The measuring tanks have closed tops, which prevent evaporation, small indicator-pipes being attached to the top of each.

---

[*] Paper read at the Pittsburg meeting of the American Institute of Mining Engineers, February, 1886.—*Transactions*, vol. xiv. pp. 727–731.

The whole apparatus being protected from radiation, the heat generated by the fuel is all measured by the increase of heat given to the water which flows through the apparatus, and by the increase of temperature of the gases of combustion as taken in the chimney over the temperature of the air supplied to the fire. This increase being in any case very slight, the amount of heat escaping up the chimney can be accurately calculated.

The Calorific Power of Fuel.—Professor Joji Sakurai,* of the University of Tokio, Japan, points out that there are two errors in the method for calculating theoretically the calorific power of a fuel as given by Dr. B. H. Paul in "Watt's Dictionary." He shows that instead of the heat units evolved on the combustion of marsh gas being 14,675, as given by Dr. Paul, the figure is really about 13,399; and further, that the calorific power of olefiant gas is 12,238. Professor Sakurai also remarks on the uselessness of all theoretical calculations of the calorific power of a coal which are evolved from the chemical analysis.

II.—*COAL.*

Discovery of Coal in Scotland.—In the cannel-coal district north of the Border boring operations were carried on by the Boghead Coal Company during the year 1885, in the immediate neighbourhood of the town of Bathgate. These eventually proved to be fruitless at the point selected. Since then Messrs. J. & W. Wood commenced to put down a bore with the diamond-drill at a point three-quarters of a mile to the north of the former bore. Boring operations were commenced in October, and in December the boring tools had got down to a depth of 170 fathoms, and in so doing had passed through a most important series of strata, containing (1) a seam of 11 inches of splendid cannel coal, which is believed to be the geological representative of the Lesmahagow gas coal; (2) a 4-inch seam of very rich and pure blackband ironstone; (3) a seam of 15 inches of fireclay; and (4) a 15-inch seam of excellent house coal, which will compare very favourably with the ell coal of the Hamilton district. It is hoped that the valuable minerals named may be found over a large tract of country.*

---

* *Chemical News* vol. lii. p. 303.

The Coal of the Zsily Valley, Transylvania.—According to R. Hofmann, † up to the present time 19 coal-beds have been discovered in this valley, 15 of which are workable, and have a total thickness of 178 feet. The chief seam has at its thickest portion a thickness of 115 feet.

The following are analyses of coals from this district:—

Deposit.	Carbon.	Hydrogen.	Oxygen + Nitrogen.
	Per cent.	Per cent.	Per cent.
Urikány	51·64	4·19	26·11
Aninosa	57·58	4·69	27·06
Kronstadt	57·59	4·81	26·27
Urikány	75·00	5·00	8·80
Urikány	83·00	5·00	9·70

The Coalfields of European Russia.—E. Agthe, ‡ manager of the Warsaw Steelworks, states that the most important of all the coalfields of Russia is that in the Donetz basin, especially on account of the good quality of the coal. There are a large number of beds, as many as 92 being found above one another at Wolynzowo. A good caking variety of coal is found, which is coked in stalls, each of which holds 6000 pud. The yield of coke by this method is from 50 to 60 per cent., but theoretically it should be very much higher.

Other varieties of coal are also found in the Donetz coalfield, and their mean percentage compositions and calorific powers will be seen from the following table:—

---

* *Iron and Coal Trades Review*, vol. xxxii. p. 14.

† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxiv. pp. 269–272 and 292–296.

‡ *Stahl und Eisen*, vol. vi. pp. 136–138.

	Long-Flame Coal.	Gas-Coal.	Forge Coal.	Coking Coal.	Anthracite.
Coke	56·33–64·61	58·37–70·40	69·33–71·67	66·64–85·13	90·70–95·80
Volatile Constituents	24·78–35·63	26·13–38·03	26·28–28·30	11·40–21·34	2·16– 8·78
Ash	2·70–11·23	1·15– 7·20	1·40– 7·00	0·91–12·08	2·06– 9·25
Sulphur	0·17– 3·82	0·15– 2·41	0·12– 1·65	0·00– 3·16	0·00– 3·00
Carbon	66·26–75·35	68·89–78·90	72·90–80·55	66·55–83·65	80·08–92·16
Hydrogen	4·32– 5·27	3·31– 5·45	4·05– 5·30	9·90– 4·41	1·32– 3·14
Oxygen and Nitrogen	14·37–17·51	12·99–20·06	12·92–18·26	8·35–16·58	2·70– 7·16
Calories	6111–7128	5903–7520	6542–7354	5802–7857	7160–8133

The coalfield of European Russia which stands next in importance is that in the Dombrowa basin, where the coal reaches a thickness of 59 feet. The output of coal from this field was in 1884 107,935,193 pud. The coal has the following composition:—

Carbon.	Hydrogen.	Oxygen + Nitrogen.
61·89–70·44	4·5–5·5	24·06–33·16

It contains a large amount of pyrites, and does not cake.

The coalfields of the Moscow basin are 268 miles broad, and have a length of 402 miles. The coal-beds are almost horizontal, and are near the surface. The best coal of the basin is very similar to Boghead coal.

In the coalfields of the Ural both anthracite and bituminous coal are found on the western slopes, as is also brown coal. The best coking coal is from the Gubachinski mine, on the right bank of the Koswa river. Its mean percentage composition is as follows:—

Carbon.	Hydrogen.	Oxygen + Nitrogen.	Ash.
68·52–79·4	4·6–5·6	6·90–15·5	2·7–16·3

Different varieties of coal are also found in the coalfields on the eastern slopes of the Ural, but mining is only carried on at three points, at Fedulow, Jeworschinsk, and Fadinaja, but only the coal found at the first of these places is of a good coking variety. It has the composition:—

Carbon.	Hydrogen.	Oxygen + Nitrogen.	Ash.
83·86	3·78	3·55	8·22

Brown coal, although it occurs at various places in Russia, is but little mined.

The Pictou Coalfield.—This field was described by Mr. H. S. Poole at the Halifax meeting of the American Institute of Mining Engineers.* Geologically it is of much interest. It is small, but with some seams of unusual thickness, the main one being 38 feet thick. The quality of the seams frequently changes to a remarkable degree within short distances. The strata dip at inclinations that carry the coal to depths of 3000 feet and more. The district is cut up by faults, and the New Glasgow conglomerate separates it from the Upper Carboniferous measure, in which no workable seams are known. The resources of coal in this field have been greatly exaggerated. An output equal to that of the United Kingdom in the last three years would more than exhaust the resources of the Pictou district, so largely is it affected by faults and the varying quality of the seams.

The Pictou field may be divided into three districts—the central or Albion, the western or Westville, and the eastern or Vale; the northern and southern portions being practically of small importance. In working the beds, as the outcrops of those opened have already been mined away, and the difficulties that attend the extraction of coal from increasing distances and greater depths present themselves more forcibly, problems arise which make it seem doubtful whether parts of the field can in the future be economically won.

In conclusion, details are given of the machinery employed at the Drummond Mine, Albion Mines, Acadia Pit, and Vale Mine.

The Coalfields of North Carolina.—In a report to the North Carolina State Board of Agriculture, Dr. H. M. Chance, describing the North Carolina coalfields, shows that there are two isolated Triassic areas in which coal has been mined, the one on the Deep River, and the other on the Dan River. In the Deep River field there are two workable coal seams, the upper one of which has an average thickness of from 2·5 to 3 feet, and the lower one 2 feet. The seams dip to the south-east at an angle of from 25° to 30°. The average composition of the coal is as follows:—

	Per Cent.
Fixed carbon	54·0
Volatile matter	30·0
Sulphur	3·6
Ash	12·0
Total	99·6

At places the coal has been converted into an anthracite type, and even into a natural coke, by the heat from dykes of trap. The cost of working the ton of coal in seams 2 feet thick is estimated at 1·5 dollar, and in seams 3 feet thick at 1·2 dollar. In the collieries of Tennessee and West Virginia, with which the North Carolina coal comes into competition, mining is carried on at the rate of 0·65 dollar per ton.

---

* *Transactions*, vol. xiv. pp. 403–410.

Mining, however, in this coalfield has not been profitable, owing to the variations in thickness and quality of the seams, to faults, trap-dykes, and various other causes.

Dr. Chance has recently examined the Triassic areas south of the Potomac, and he is of opinion that the difficulties to be overcome when mining for coal in Triassic districts, arise mainly from the structure of the deposits, due to the presence of faults and numerous trap-dykes. In the districts south of the Potomac the coal has been so completely crushed along the faults that it is usually of little commercial value. At the same time the continuity of the beds has been broken and their dip disturbed and rendered irregular. The cost of working the coal is thus rendered very uncertain, more especially as the trap-dykes occurring are even more injurious to the coal than are faults. The dykes are accompanied by displacement of the beds on either side, and change the nature of the adjacent coal. At times the coal has been ruined by the heat, but at others a natural coke has been produced which is more valuable than the original coal. When more than a few feet thick, trap-dykes are so expensive to penetrate that they are almost insurmountable obstacles. Again, the trap sometimes penetrates the coal-bearing strata in intrusive sheets, approximately parallel with the planes of bedding, and these are even more troublesome to the miner than the vertical dykes.

The Richmond coalfield is of the same age and general character as the Deep River deposit, but the seams are thicker and the coal is of better quality.

The Jellico Coalfield, United States.—The Jellico Mountain is a spur from the great Cumberland water-divide which shoots off to the north at a point where the divide changes its usual north-east and south-west course to the east.

The coal occurring at this point contains about 60 per cent. of fixed carbon, 35 per cent. of volatile matter, some moisture, and 2 to 3 per cent. of ash. It burns freely and has no tendency to coke. Geologically the coal belongs to the lower coal measures as classed in Pennsylvania. The field was unworked four years ago, and is making rapid progress. There are four collieries, two in Tennessee, and two in Kentucky, the daily output being about 1200 tons.*

The Classification and Composition of Pennsylvania Anthracites.—One of the most extensively discussed questions connected with the Pennsylvania coal districts is the classification of the coals. Mr. C. A. Ashburner † suggests the following:—

Classes of Coals.	Ratio $\frac{C.}{Vol. H.C.} : 1$
Hard dry anthracite	from 99 : 1 to 12 : 1
Semi-anthracite	,, 12 : 1 ,, 8 : 1
Semi-bituminous	,, 8 : 1 ,, 5 : 1
Bituminous	,, 5 : 1 ,, 0 : 1

In this classification the accidental impurities are disregarded in the analyses, and the fuel constituents alone considered, in order to calculate the fuel ratio by dividing the amount of fixed carbon by the amount of volatile hydrocarbons.

The coals of the producing collieries during the year 1884, have been classified under the ten general heads in the following table, a method extensively made use of by the coal trade:—

Character of Coal.	Number of Collieries.	Production in '884.	Percentage of Total Production.
		Tons.	
1. Free burning white ash .	213	17,109,523	52·41
2. Hard white ash . . .	105	9,206,639	28·20
3. Wyoming red ash . .	14	1,727,965	5·30
4. Lehigh red ash . . .	11	1,510,494	4·63
5. Spamokin	29	1,409,854	4·32
6. Lykens Valley red ash .	8	1,145,008	3·50
7. Trevorton	14	227,467	0·71
8. Lorberry red ash . . .	2	116,695	0·36
9. Bernice white ash . .	4	101,836	0·31
	1	86,018	0·26
Totals .	401	32,641,499	100·00

If the amount of combustible matter in a coal is any criterion of its fuel value, an examination which has recently been made shows how little is known of the actual value of the different coals burnt. In order to test the value to be attached to the judgment of the trade in discriminating between different coals, an experienced miner and shipper of anthracite was requested to name a number of coals which were credited by most consumers with equal value. Thirty-three samples of these coals were collected and analysed (the results being given in the author's paper). From these analyses the following averages were obtained, showing the mean character of the coals from the more important beds :—

---

* *Iron Age*, vol. xxxvi. No. 22.

† Paper read at the Pittsburg meeting of the American Institute of Mining Engineers, February, 1886.—*Transactions*, vol. xiv. pp. 706-727.

Name of Bed.	Chemical Analysis.					Sp. Gr.	Percentage of Constituents of Fuel.		Fuel Ratio.
	Water.	Volatile Matter.	Fixed Carbon.	Sulphur.	Ash.		Fixed Carbon.	Volatile Matter.	
Wharton .	3·713	3·080	86·404	0·585	6·218	1·620	96·56	3·44	28·07
Mammoth .	4·119	3·084	86·379	0·496	5·922	1·617	96·55	3·45	27·99
Primrose .	3·541	3·716	81·590	0·499	10·654	1·654	95·64	4·36	21·93
Mammoth .	3·163	3·717	81·143	0·899	11·078	1·657	95·62	4·38	21·83
Red Ash .	3·008	4·125	87·982	0·506	4·379	1·584	95·52	4·48	21·32
Buck Mt. .	3·042	3·949	82·662	0·462	9·885	1·667	95·44	4·56	20·93
Seven Foot .	3·410	3·978	80·868	0·512	11·232	1·651	95·31	4·69	20·32
Mammoth .	3·087	4·275	83·813	0·641	8·184	1·631	95·15	4·85	19·62
Mammoth .	3·412	4·381	83·268	0·727	8·203	1·575	95·00	5·00	19·00
B. (Loyalsock)	1·295	8·100	83·344	1·031	6·230	...	91·14	8·86	10·29

The analyses given above are of coals from all sizes (mixed), which were shipped from the different collieries. It is found in practice that after screening, the purity of the different sizes of coal is very different. This is shown by the following analyses of specimens collected from the screen-building of the Lehigh Company :—

Kind of Coal.	Size, Inches.	Water.	Volatile Matter.	Fixed Carbon.	Sulphur.	Ash.
Egg	2·5 to 1·75	1·722	3·518	88·489	0·609	5·662
Stove	1·75 to 1·35	1·426	4·156	83·672	0·572	10·174
Chestnut . . .	1·25 to 0·75	1·732	4·046	80·715	0·841	12·666
Pea	0·75 to 0·50	1·700	3·894	79·045	0·697	14·664
Buckwheat . . .	0·50 to 0·25	1·690	4·058	76·918	0·714	16·620

In preparing the coal for market, pieces of what is known as *bony coal* are picked out as worthless. The lustre of this coal is dull, and it has the appearance of cannel. Much of it is believed to be as good a fuel as that which is shipped from the same colliery to market. In fact, analyses recently made of this coal from a certain colliery proved it to contain more fuel constituents than the coal which was sold to the trade.

New Zealand Coals.—The following are the results of assays of the New Zealand coals exhibited at the Indian and Colonial Exhibition:—

Description.	Fixed Carbon.	Volatile Hydrocarbons.	Water.	Ash.	Evaporative Power.
Anthracite from Acheron, Canterbury	84·12	2·06	1·80	12·12	5·17
Altered brown coal, Malvern Hills, Canterbury	68·54	19·89	4·15	7·42	8·87
Altered brown coal, ,, ,,	53·29	32·04	12·65	2·02	6·92
Brown coal, Malvern, Canterbury	49·99	35·42	11·79	2·80	6·49
Brown coal, Homebush Colliery, Malvern, Canterbury	47·70	30·92	19·20	2·20	6·20
Glance coal, Rakaia Gorge, Canterbury	64·51	21·27	6·76	7·46	8·30
Brown coal, ,, ,,	50·12	21·61	24·09	4·18	6·50
Bituminous coal, Grey River, Westland	62·37	29·44	1·99	6·20	8·01
Pitch coal, Black Creek, Grey River, Westland	60·20	29·97	8·01	1·82	7·82
Pitch coal, Grey River, Westland	34·80	55·40	6·20	2·60	4·56
Bituminous coal, Preservation Inlet	60·88	20·69	4·33	6·19	7·91
Bituminous coal, Westport	59·75	32·14	3·97	4·14	7·76
Bituminous coal, Mokihinui, Westport	55·59	38·86	3·16	2·39	7·20
Brown coal, Westport	56·01	37·17	2·60	4·22	7·28
Brown coal, Mokihinui, Westport	57·92	34·94	3·96	3·18	7·50
Bituminous coal, Brunner Mine	56·62	35·68	1·59	6·11	7·36
Bituminous coal, Otamatawea Creek	52·89	36·63	2·19	8·29	7·90
Black coal, Kawa River	50·15	42·63	4·18	3·04	6·52
Glance coal, Whangarei, Auckland	50·11	38·68	8·01	3·20	6·50
Pitch coal, Kama Mine, Whangarei, Auckland	50·01	37·69	9·61	2·69	6·50
Pitch coal, Walton's Mine, ,, ,,	38·80	41·20	7·20	12·80	4·96
Brown coal, Waikato, Auckland	50·01	29·97	19·82	2·20	6·50
Bituminous coal, near Cape Farewell	48·59	43·17	2·18	6·06	6·63
Brown coal, Shag Point, Otago	45·30	30·10	19·20	5·40	5·66
Brown coal, Kaitangata, Otago	44·11	38·32	15·44	2·13	5·74
Brown coal, ,, ,,	39·41	37·25	19·61	3·73	5·12
Bituminous coal, S. of Ross, Southland	42·53	31·43	6·58	19·46	4·16
Brown coal, Okoko, Waipa, Auckland	39·83	33·74	22·21	4·22	5·17
Brown coal, Springfield Colliery	38·00	31·50	18·60	11·90	4·90

Assays of Coal.—The following assays of coal are given by Mr. Hill in *Van Nostrand's Magazine*:—

	Pittsburg.	Winifrede.	Campbell's Creek.	Peach Orchard.
Fixed carbon	59·88	57·21	53·24	52·83
Volatile matter	33·71	37·58	34·23	36·83
Moisture	1·87	1·93	2·15	4·60
Sulphur	0·44	0·56	0·72	0·76
Ash	4·10	2·72	9·66	4·98
Totals	100·00	100·00	100·00	100·00

III.—*CHARCOAL.*

A Sheet Iron Charcoal Kiln.—A long description of Lovelace's patent iron charcoal kiln is given by Mr. D. G. Stone in the *Mining Journal* of Marquette, Michigan. The object of the invention is to provide a portable kiln for charring wood, and to render practicable the employment of sheet iron in the construction of the body of the kiln by placing the seat of fire as far as possible away from the iron shell. The fireplace is built in the ground below the level of the kiln floor, and communicates directly with a horizontal air-flue, which is also formed in the ground. A circular wall of brick serves as a foundation for a dome-shaped hood, which forms the body of the kiln. Access is afforded through a doorway formed partly in the foundation wall and partly in the lower portion of the hood. Opposite this, in the upper part of the hood, is another door. In the foundation wall are passages for the escape of gas. At the top of the dome is a circular opening closed by a hinged conical cap for controlling the escape of gases. The dome is composed of iron plates riveted together. The horizontal draft-flue for the central fireplace extends from a point outside the kiln to a point immediately under the seat of fire, and conducts air from the exterior to the grate in the centre of the kiln, whence it passes to the interior.

The size of kiln recommended is that of 25 cords capacity. One of this size can be filled in a day of 10 hours, and emptied in the same time. The contents should be charred in 4 days of 24 hours. A set of these kilns have been in continuous operation since August 1885 at M'Millan, Michigan.

Charcoal Ovens in Tennessee.—Mr. J. W. Courtney, of the Warner Furnace, Tennessee, gives an account * of the charcoal ovens in Hickman County, Tennessee. The Warner Company have 20 brick ovens that hold from 49 to 56 cords of wood each. They are circular, with an average diameter of 30 feet, and are 10 to 14 feet high. An aperture at the top and doors at the side are closed during the carbonising process. Under each oven is a small furnace where fires are kindled. A pipe or chimney leads from each oven to a main gas-distributor, through which the gas resulting from carbonisation is drawn by an exhaust fan and forced into a condenser, where crude pyroligneous acid is formed from which tar and alcohol are extracted. The remainder of the gas is carried into a separate main, and supplies fuel for the ovens, for heating the boilers, &c. The tar is forced into the furnace stack by steam injectors. It requires twelve days from the time the oven is charged till the charcoal is taken out and the oven charged again. From a cord of wood weighing 4000 lbs. are obtained 1200 lbs. charcoal, nearly 200 gallons pyroligneous acid, and 6000 cubic feet of non-condensable gases. The average yield of charcoal is 50 to 57 bushels, while only about 40 bushels to the cord are yielded by the old pit process. It is estimated that 500 cubic feet of non-condensable gas are equal to a bushel of charcoal; so a cord of wood by this process yields 50 bushels of charcoal and gas equal to 12 bushels, besides the tarry product, altogether adding 65 per cent. to the fuel value of a cord of wood. The use of part of the gas in firing the ovens makes a great saving. The ovens are built of hard brick, and cost about 675 dollars each. A new blast furnace is being built near the works, 45 feet high, 9 feet bosh, 4 feet hearth. It is calculated that the fuel to a ton of iron will cost not more than 3 dollars.

---

* *Iron Age*, vol. xxxvi. No. 20.

IV.—*COKE.*

The Manufacture of Coke in the United States.—Mr. J. D. Weeks † describes at length the different coalfields of North America from which the coal is obtained which is used in the manufacture of coke. The coal comes mainly from the four following coal-basins—the *Appalachian*, the *Illinois*, the *Missouri*, and the *El Moro*, Colorado, by far the largest quantity of the coal used coming from the Appalachian field, only about 3 per cent. coming from the Illinois, Missouri, and Colorado basins. The Appalachian coalfield commences near the northern boundary of Pennsylvania, and extends in a south-westerly direction for 750 miles, following the western line of the Alleghany Mountains, and ends at Tuscaloosa, Alabama; its area is about 70,000 square miles. The coke industry is chiefly carried on in the Connellsville district of Western Pennsylvania, the coke produced there being considered as the standard for the United States. The coal in the northern and eastern portions of the field is, as a rule, of a better coking variety than that in the southern and western portions, but anthracite is also found.

---

† *Mineral Resources of the United States for* 1883 *and* 1884. Washington, 1885, pp. 144–213.

The coal measures of the Illinois basin very nearly equal in area those of the Appalachian basin, covering about 47,188 square miles, but the coals do not possess such good coking properties, and they are, as a rule, richer in ash and sulphur than the coals of the Appalachian and Missouri basins.

The Missouri basin is the largest in area of all the coalfields of the United States, and it is estimated to have an area of 84,343 square miles.

Not much is known concerning the El Moro basin, but coke is made at several places from the coal.

There were in the United States in 1884, 19,557 coke ovens. These belonged to 250 works, of which 145, or 58·6 per cent., were in Pennsylvania; 27, or 10·8 per cent., in West Virginia; 19, or 7·6 per cent., in Ohio; and 13, or 5·2 per cent., in Tennessee. In each of the other states the number was less than 10. At the close of 1884 812 new coke ovens were in course of construction.

The following table shows the percentage yield in coke of the coal coked in the several divisions of the United States for the years 1880–1884. In several cases the figures are estimates, a great deal of the coal coked being in the form of slack, which is charged into the oven without weighing, and in such cases only a rough estimate of the quantity so charged could be given:—

States and Territories.	1880.	1881.	1882.	1883.	1884.
Alabama	57	59	58	60	60
Colorado	49	50	57	60	64
Georgia	60	60	60	60	60
Illinois	41	42	45	43	43
Indiana	...	...	...	...	...
Indian Territory	62	62	62	62	62
Kansas	64	64·4	65	62·9	62¼
Kentucky	60	60	59	60	64
Montana	...	...	...	...	46
New Mexico	...	...	66⅔	57¼	57½
Ohio	58	59	57	58	58
Pennsylvania	65	64	64	65	62
Tennessee	60	60	60	62	63
Utah	50	...	50	...	...
Virginia	...	...	...	64½	64¼
Washington	...	...	...	...	57½
West Virginia	60	61	63	63	62

The districts in which coke is produced are described by the author in detail, and he gives particulars as to the comparative values of the different coal-seams found.

The following are results of assays (1) of the typical Connellsville coal, and (2) of the coke produced from it in the ovens of the H. C. Frick Coke Company :—

	1.	2.
	Per cent.	Per cent.
Fixed carbon	59·616	89·576
Volatile matter	30·107	0·460
Sulphur	0·784	0·821
Ash	8·233	9·113
Water	1·260	0·030
Totals	100·000	100·000

Colour of ash, reddish grey ; coke, per cent., 68·633 ; sulphur left in coke produced in the laboratory, 0·512.

Percentage of sulphur in coke	0·746
Percentage of ash in coke	11·995
Percentage of carbon in coke	87·250
Total	99·991

Other average assays of Connellsville coke and analyses of the ash are also given. The coke is of silvery lustre, cellular, with a metallic ring, tenacious, comparatively free from impurities, and is capable of bearing a heavy burden in the furnace.

The following are assays of other varieties of coal and coke :—

Coketon, Pennsylvania, coal and coke :—

	Coal.		Coke.		
	Top of Seam.	Bottom of Seam.	Unwashed.	Washed.	
				No. 1.	No. 2.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Fixed carbon	70·91	60·57	86·58	89·15	83·93
Volatile matter	25·52	18·18	1·26	...	...
Sulphur	0·23	1·17	1·49	1·20	1·27
Ash	3·34	20·08	10·67	9·65	14·80
Totals	100·00	100·00	100·00	100·00	100·00
Silica in ash	...	...	...	4·67	6·12

Latrobe District.—Coal and coke from the Irwin :—

	Slack.		Coke.
	Unwashed Coal.	Washed Coal.	
	Per cent.	Per cent.	Per cent.
Fixed carbon	56·57	54·88	88·240
Volatile matter . . .	31·68	38·13	1·384
Sulphur	1·26	0·96	0·962
Ash	11·08	6·98	9·414
Totals . .	100·59	100·95	100·000

Alleghany Mountain District.—Coal and coke from Bed B :—

	Coal.	Coke.
	Per cent.	Per cent.
Fixed carbon	61·843	87·58
Volatile matter	27·225	...
Sulphur	2·602	1·06
Ash	6·930	11·36
Water	1·400	...
Totals . . .	100·000	100·00

Upper Freeport coal, Cambria County :—

	Per Cent.	Per Cent.
Fixed carbon	70·518	74·950
Volatile matter	12·250	18·630
Sulphur	1·459	4·860
Ash	5·058	1·400
Water	0·715	0·160
Totals . . .	90·000 *	100·000
Phosphorus	...	0·011

Coal and coke from the Snow-Shoe Basin, Pennsylvania :—

	Coal.		Coke.		
	Snow-Shoe Coal and Coke Co.	Bed E.	Snow-Shoe Coal and Coke Co.	Bed E.	Bed E.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Fixed carbon	70·416	68·937	82·626	90·672	89·208
Volatile matter . . .	24·560	25·580	2·950	0·564	0·468
Sulphur	0·964	0·613	1·104	0·704	0·770
Ash	3·410	3·590	12·330	7·910	9·444
Water	0·650	1·280	0·990	0·150	0·110
Totals . .	100·000	100·000	100·000	100·000	100·000

---

* 100·000 in orginal.

(*a.*) Coke from the coal of the Broad Top District.
(*b.*) Coke from the coal of the Pittsburg District:—

	A.	B.
	Per cent.	Per cent.
Fixed carbon	89·28	86·990
Sulphur	1·06	0·798
Ash	9·66	11·899
Water	...	0·313
Totals	100·00	100·000

Beaver District.—Assays of coal and coke from Beaver Falls (Lower Bench):—

	Coal.	Coke.
	Per cent.	Per cent.
Fixed carbon	54·619	84·727
Volatile matter	38·110	0·633
Sulphur	0·791	1·994
Ash	4·080	12·636
Water	2·400	0·010
Totals	100·000	100·000

Alleghany Valley District.—Assays of Upper Freeport coal and coke, Armstrong County, Pennsylvania:—

	Stewardson Coal.	Mahoning Coal.	Kittanning Coke (washed).
	Per cent.	Per cent.	Per cent.
Fixed carbon	55·545	54·996	87·22
Volatile matter	35·520	34·810	...
Sulphur	0·835	1·054	1·23
Ash	6·630	7·690	11·43
Water	1·470	1·450	...
Totals	100·000	100·000	99·88

Assay of coke made at the Red Bank Furnace, Clarion County, Pennsylvania:—

	Per Cent.
Fixed carbon	88·360
Volatile matter	1·106
Sulphur	1·076
Ash	9·228
Water	0·230
Total	100·000

Low Grade District.—Assays of coal and coke from Fairmont City, Pennsylvania:—

	Unwashed Slack.	Washed Slack.	Coke.
	Per cent.	Per cent.	Per cent
Fixed carbon	51·397	54·223	85·777
Volatile matter	35·130	35·825	0·623
Sulphur	1·988	1·312	2·107
Ash	10·225	7·340	11·463
Water	1·260	1·300	0·300
Totals	100·000	100·000	100·270

Assays of coal and coke from Jefferson County:—

	Coal.	Coke.
	Per cent.	Per cent.
Fixed carbon	62·524	88·95
Volatile matter	30·800	1·42
Sulphur	0·776	0·90
Ash	4·800	7·95
Water	1·100	0·78
Totals	100·000	100·00

Assays of coal and coke from Clearfield County:—

	Coal.	Coke.
	Per cent.	Per cent.
Fixed carbon	59·904	61·653
Volatile matter	32·450	31·060
Sulphur	1·296	1·487
Ash	5·400	4·950
Water	0·950	0·940
Totals	100.000	100·090

The coal from Clearfield County is firm, bright, and bears transportation well. The coke is bright, of great calorific energy, and is capable of sustaining a heavy burden.

The following are assays of the Bloss and Seymour coals and cokes from various parts of the coalfield :—

Assays of Bloss and Seymour, Pennsylvania, Coals.

	Bloss.					Seymour.
	Upper Bench.	Middle Bench.	Lower Bench.	Run of Mine.	?	
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Fixed carbon . .	71·697	64·306	63·428	71·847	69·655	71·574
Volatile matter . .	20·755	20·640	18·790	20·240	21·474	21·586
Sulphur . . .	1·023	0·914	0·602	0·548	0·872	0·907
Ash	5·335	13·200	16·070	5·105	7·065	4·753
Water . . .	1·190	0·940	1·110	2·260	0·911	1·180
Totals .	100·000	100·000	100·000	100·000	99·977	100·000 *

Assays of Bloss and Seymour, Pennsylvania, Cokes.

	Bloss.					Seymour.	
	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 1.	No. 2.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Fixed carbon .	83·371	83·922	83·579	80·927	85·073	84·760	90·650
Volatile matter	0·845	0·572	0·550	1·732	0·838	0·722	0·625
Sulphur . . .	0·644	0·679	0·686	0·764	0·779	0·998	0·850
Ash	14·550	14·587	15·105	15·427	13·288	13·345	7·655
Water . . .	0·590	0·240	0·080	1·150	0·022	0·175	0·220
Totals . .	100·000	100·000	100·000	100·000	100·000	100·000	100·000

Connellsville and Virginian Coke.—A. Farrell † gives the following as representing the average composition of the coke prepared by the Pocohontas Company, Virginia :—

Fixed Carbon.	Volatile Matter.	Sulphur.	Water.	Ash.	Total.
90·02	1·35	0·67	0·21	7·75	100·00

The coke is fairly strong and dense, and it has been employed in the working of a blast furnace belonging to the Lynchburg Iron Company. This furnace is 55 feet high and 13 feet in diameter, and it has 10 iron-pipe stoves, the blast being heated to 800° F. The grade of iron produced was, to a large extent, No. 1 or No. 2 foundry. The ore smelted was chiefly a brown hæmatite, some soft specular ore being also employed. The composition of the ore and limestone was approximately the same during comparative furnace trials of Pocohontas and Connellsville coke, the results of the trials being shown in the following table :—

---

* 99·900 in original.

† *Iron Age*, vol. xxxvii. No. 6.

Variety of Coke.	Per Ton of Pig Iron made.		
	Coke.	Ore.	Limestone.
	Tons.	Tons.	Tons.
Pocohontas	1·49	2·02	0·88
Connellsville	1·50	2·01	1·03

The average daily yield of pig iron, including time of blowing in, stops, &c., was 40·8 tons.

Utilisation of Coke-Oven Gases.—At the Karl pit of the Cöln Colliery Company (Frohnhausen district, Prussia), the gases from 50 coke ovens are employed for heating 6 Steinmüller tubular boilers, each with a heating surface of 915 square feet. It is estimated that in consequence of this utilisation of gas, 6400 tons of coal are saved annually.*

The Cost of the Production of Coke at Pittsburg.—In connection with the strike in the Connellsville district, United States, there has been considerable discussion in the Pittsburg papers as to the cost of production of coke, and the following are two of the estimates which have been published—the first by a miner, the second by a manufacturer. The miner's estimate represents the daily expenses of a bank of 40 ovens, 20 being drawn each day, and is as follows † :—

	Dollars.
Cost of coal (½ cent per bushel)	12·35
70 trucks of coal at 27 cents	18·90
Charging ovens	2·00
Levelling	1·60
Drawing 20 ovens	11·00
Hauling and feeding stock	2·75
Foreman's wages	2·00
Oil, posts, rails, &c.	1·50
Interest on capital	2·50
Syndicate's commission for handling coke	3·65
Total	58·25
58·8 tons of coke at 1·20 dollars	70·56
Less daily expenses	58·25
Balance . . .	12·31

---

* *Zeitschrift für das Berg- Hütten- und Salinenwesen im preussischen Staate*, vol. xxxiii. pt. 3.

† *Iron Age*, vol. xxxvii. No. 3.

This estimate places the cost of coke in the trucks, ready for shipment, at 98·9 cents per ton.

The manufacturer's estimate is as follows:—

	Dollars.
Coal for a ton of coke	0·38
Drawing and loading	0·25
Hauling and general expenses	0·10
Repairs	0·10
Interest on capital, &c.	0·32
Total	1·15

The Relative Value of Charcoal and Coke in Blast-Furnace Practice.—E. Belani* points out that in order to estimate the working value of a fuel in the blast-furnace the cubic contents of the zone of combustion must be taken into consideration, as well as the rapidity of the combustion; as the greater the quantity of heat which the unit of fuel produces when burnt in the unit of time, the less will be the loss of heat in the same period, and the greater will be the quantity of heat which will be available for absorption by the charge. Consequently, with different fuels, the least quantity required for a given purpose will fall to that one which, in the unit of time, develops the maximum quantity of heat.

The heat developed by the unit weight of fuel in the unit of time depends (1) on the size of the surface exposed to the action of the blast, and (2) on its relative combustibility. This latter depends on the state in which the carbon is present, and is in inverse, though undetermined, ratio to its specific gravity. Further, the more combustible a fuel is, the more of it will be burnt away in a given time, and the greater will be the surface exposed to the blast during that period; consequently, combustibility and exposed surface are relatively identical.

In discussing the relative advantages of charcoal and coke in blast-furnace work for the production of pig iron, the author remarks that the relatively lower quantity of heat developed by the coke in the unit of time (which consequently necessitates the use of a larger quantity of fuel) is one of the chief causes for the poorer quality of the pig produced when coke has been used, than when charcoal has been employed. If it were possible to obtain the coke in as voluminous a condition as the charcoal, the results obtained would probably be similar.

---

* *Stahl und Eisen*, vol. v. pp. 603–610.

The Blast-Furnace Value of Coke.—Discussing whether the densest varieties of coke are the best for blast-furnace purposes, H. Kutscher* notes that the variation in the rapidity of combustion depends greatly on the surface exposed to the action of the blast, and in order to obtain some idea as to the way in which different varieties of fuel are attacked by a current of carbonic anhydride, he instituted the following experiments: The materials to be compared with each other were all powdered to the same degree of fineness—to lumps of a few millimetres; they were then well dried, and each, when weighed, was placed in a porcelain boat in a glass combustion tube. The tube was then filled with carbonic anhydride, and was heated to a bright red-heat, and for a space of about half an hour a slow current of carbonic anhydride was passed through it. After this period had elapsed the tube was cooled and the porcelain boat withdrawn. The substance contained in the boat was then re-weighed, with the following results:—

	Loss of Weight in Experiment	
	I.	II.
	Per cent.	Per cent.
Boxwood charcoal	12·25	12·55
Soft charcoal from willow-wood	11·18	...
Very hard, largely porous coke from Pluto coal	0·30	0·36
Firm coke, from the same coal	0·30	0·23
Pressed coke	0·30	0·39
Ordinary trade graphite, containing 36·5 per cent. carbon	4·33	4·42

These experiments show very forcibly the very rapid action of a current of carbonic anhydride on charcoal, as compared with the very slight extent to which the coke was acted upon in the same time.

The Comparative Value of Coal, Coke, and Charcoal for Blast-Furnace Purposes.—Dr. W. Thörner † describes a number of experiments relating to this subject. The results show:—

1. That charcoal consists of a large number of more or less regularly arranged cells, which are joined to one another longitudinally. The walls of the cells are readily porous for gases, and are very easily oxidisable.

---

* *Stahl und Eisen*, vol. v. pp. 794–801.

† *Ibid.*, vol. vi. pp. 71–83.

That coke, on the other hand, contains generally separate unconnected cells, or groups of cells, the walls of which are composed of a dense and vitreous mass which does not admit of the passage of gas through it, and is exceedingly difficult to oxidise.

2. That the relatively smaller action in blast-furnace practice of coke as compared with charcoal, would be increased were it possible to cause the structure and character of coke generally to more closely resemble that of charcoal, either by the formation of a coke more porous, though sufficiently strong, or with greater certainty, by rendering the coke-substance more easily oxidisable.

A large number of samples of coke, &c., were examined with the results shown in the following table:—

Variety of Fuel.	Colliery.	Ash, Per Cent.	Specific Gravity.		In 100 Grammes Coke.		Volume of 100 Grammes of Coke.
			Apparent.	Real.	Cell-space, Cubic Centimetres.	Coke-substance, Cubic Centimetres.	
1. Retort coke, Osnabrück gasworks	Pluto . . .	3·8	1·825	0·858	61·6	54·8	116·4
2. Retort coke, Osnabrück gasworks	Friedrich d. Gr. .	7·5	1·811	0·868	60·0	55·2	115·2
3. Compressed coke, Cologne - Müsen Company . .	...	7·7	1·852	0·984	47·6	54·0	101·6
4. Compressed coke, Cologne - Müsen Company . .	⅞ Morgensonne ⅛ Langenbrahm	6·9	1·786	0·969	47·2	56·0	103·2
5. Ordinary Coppée coke, Cologne-Müsen Company	...	7·99	1·880	0·926	54·8	53·2	108·0
6. Carlsglück and Planetenfeld, Dortmund coalfield .	...	7·8	1·825	0·909	55·2	54·8	110·0
7. Maassen, low level	Maassen Colliery	7·3	1·852	0·890	58·4	54·0	112·4
8. Westhausen, Bodelschwingh .	...	10·6	1·852	0·919	54·8	54·0	108·8
9. Neu-Iserlohn, Langendreer . .	...	8·8	1·852	0·874	60·4	54·0	114·4
10. Dannenbaum, Bochum . .	...	8·45	1·894	0·890	59·6	52·8	112·4
11. Germania works, Grevenbrück .	...	7·6	1·909	0·903	58·4	52·4	110·8
12. Heinrichshütte, Au, a. d. Sieg .	...	7·6	1·887	0·980	49·0	53·0	102·0
13. Meiler coke, Silesia	...	2·9	1·488	1·046	28·4	67·2	95·6
14. Pine charcoal .	...	2·9	1·626	0·382	200·4	61·6	262·0
15. Oak charcoal .	...	2·45	1·347	0·587	96·2	74·2	170·4
16. Beech charcoal .	...	2·10	1·481	0·594	100·8	67·6	168·4
17. Birch charcoal .	...	1·65	1·351	0·484	132·5	74·0	206·5
18. Anthracite . .	Piesberg . .	9·30	1·666	1·572	3·6	60·0	63·6
19. Bituminous coal .	Borgloh . .	8·30	1·323	1·300	1·4	75·6	77·0

On comparing the above results, it will be observed that amongst the coke-samples examined, that produced in meilers has the least porosity—28·4 cubic centimetres per 100 grammes, and the ordinary retort coke the greatest—61·6 cubic centimetres. The porosity of coke produced in ordinary ovens varied from 54·8 to 59·6 cubic centimetres per 100 grammes, a notable exception, however, being the so-called "pressed coke," Nos. 3 and 4, produced on the Lürmann system, in which the porosity is only about 47 cubic centimetres on the same weight of coke.

The porosity of the charcoal varied between 96·2 cubic centimetres and 200·4 cubic centimetres per 100 grammes, and it is curious that pine charcoal, the most porous of the varieties examined, possessed the densest charcoal-substance.

Microscopical investigation of the form and size of the cells and the strength of the cell-walls, necessitates the use of thin sections, and these were photographed under the microscope, and engravings of the photographs so obtained accompany the paper. The sections were somewhat difficult to produce owing to the extreme brittleness of the material, and the method which was finally adopted is described by the author.

On examining the sections microscopically, it was observed that the very smallest details of the structure of the original wood had been preserved in the charcoal, and the arrangement of the cells explained this fact, as it enabled the gaseous products of the coking process to escape easily; it consequently also tends to explain the ease with which charcoal burns, the author remarking that where the waste products could escape the furnace gases could enter. Besides which the charcoal-substance had not been fused, but remained in an easily combustible form. The coke, on the other hand, was found to be fused into a perfectly dense, impenetrable, vitreous mass.

Experiments on the resistance to crushing stress shown by the different varieties of coke were found to give erroneous results when the coke was carefully turned into a cylindrical form, and the author remarks that the use of cubes, as employed by Fulton * in his experiments, was open to the objection that it was almost impossible to obtain from such a brittle material cubes of exactly the same size, and it was further found that the cubes produced were never free from slight cracks; it was, however, shown by the experiments with cylindrical test pieces that, as a general rule, the crushing strain of coke

---

* *Journal of the Iron and Steel Institute*, 1884, p. 698.

was from 0·97 to 1·73 kilogramme per square millimetre of surface; but as the results agreed together very badly, a further series of tests were made in which the coke was crushed to pieces of about 10 millimetres diameter, surrounded by an iron jacket, and placed under a piston, and then submitted to a crushing stress; the volume to which the coke was compressed being noted after increasing loads, as it was considered that these conditions would more nearly represent those actually occurring in the blast-furnace than would otherwise be possible. The result showed that the relative strength or compressibility was, as a rule, directly dependent on the porosity both in the case of charcoal and in that of coke.

The relative resistance of coke and of charcoal to the action of carbonic anhydride, and of the blast, have, the author remarks, already been investigated, in particular by Sir Lowthian Bell; they were further investigated by himself, and he describes at length the actual method he employed. On subjecting the pieces of coke and charcoal that were to be examined to a preliminary heating to a white heat in a current of hydrogen, it was found that there was a considerable loss. The actual decrease in the weight which was observed is shown in the following table, the numbers referring to the specimens given in the first table:—

	Decrease in Weight. Per cent.
2. Retort coke	0·25
3. Compressed coke	1·40
4. Compressed coke	1·15
5. Coppée coke	1·13
6. Carlsglück, &c., coke	1·55
7. Maassen coke	1·70
8. Westhausen coke	1·70
10. Dannenbaum coke	0·75
13. Meiler coke	29·70
14. Pine charcoal	17·90
15. Oak charcoal	13·20
16. Beech charcoal	11·80
17. Birch charcoal	13·20

This great loss, especially in the case of the meiler coke, is not to be explained by the evolution of water, as, if this had been the cause, heating to 150° C. would be sufficient; but this is not the case, and the author is of opinion that the loss is due to the escape of hydrocarbons from the cells, and he points out that those fuels, charcoal and meiler coke, which give the best reducing action in the blast-furnaces contain the greatest relative quantities of hydrocarbons, or other decomposition products.

In examining the action of carbonic anhydride and air on the different varieties of coke and charcoal, 1 gramme of each sample of coke, and 0·5 gramme of each variety of charcoal, were placed in a platinum boat, and heated in a current of air or carbonic anhydride for different periods, with the results shown in the accompanying table:—

Fuel.	Heated in Carbonic Anhydride (loss per cent.)			Heated in Air for 10 Minutes, 4·5 Litres air being used (loss per cent.)
	For 15 Minutes. 500 c.c. CO_2 used.	For 30 Minutes. 1 Litre CO_2 used.	For 2¼ Hours. 5 Litres CO_2 used.	
1. Retort coke . .	...	10·6	27·2	46·8
2. Retort coke . .	...	11·8	38·6	45·0
3. Compressed coke .	...	13·8	38·0	51·0
4. Compressed coke .	...	8·4	27·2	48·9
5. Coppée coke . .	...	8·7	27·5	50·1
6. Carlsglück coke .	...	8·3	29·3	54·4
7. Maassen coke . .	...	8·0	29·3	51·5
8. Westhausen coke .	...	9·5	26·2	52·9
9. Neu Iserlohn coke .	...	12·2	34·0	46·8
10. Dannenbaum coke .	...	6·8	22·6	57·1
11. Germaniahütte coke	...	8·9	32·0	52·1
12. Heinrichshütte coke	...	6·9	24·3	52·5
13. Meiler coke . .	...	45·6	100·0	87·7
14. Pine charcoal . .	61·1	96·3	...	100·0
15. Oak charcoal . .	48·8	85·0	...	78·6
16. Beech charcoal .	60·4	95·0	...	80·3
17. Birch charcoal .	68·0	95·0	...	100·0
18. Anthracite . .	...	...	...	45·4
19. Bituminous coal .	...	...	...	74·4

In conclusion, the author remarks that his experiments prove the correctness of the theoretical calculations of Belani and of Kutscher, both of whom are of opinion that the ideal coke must be one resembling charcoal to as great an extent as possible.

The Relative Values of Coal and Coke for Foundry Purposes.—H. van Atta[*] states that at the works under his charge it has been found that every attempt to use a less weight of coke than of coal on the charges resulted in unsatisfactory iron. He adds that the construction of the cupolas employed at the works is such that a coke-bed could not be used in the tests, and further, that the usual cast is 14 to 16 tons of iron, with an expenditure of 1 lb. of coal per 7·2 to 7·5 lbs. of iron. In the tests with coke as fuel the following results were obtained:—

1. All attempts to melt with a less weight of coke than the amount of

---

[*] *Iron Age*, vol. xxxvii. No. 15.

coal otherwise used on the charges resulted in the production of dull and uneven iron.

2. All coke on charges produced equally fluid but less lively iron.

3. The best results were obtained when equal amounts of coal and of coke were used on the charges, as the resulting iron came down at a proper and uniform heat.

4. By the use of coke it was found possible to save 30 minutes on the heat, the cupola dumped much cleaner, and less pressure of blast was required.

Owing to the difference in price of coal and coke the iron run down with coke was relatively dearer than that obtained by the use of coal. The author is, however, of opinion that apart from the relative powers of coke and coal to satisfactorily melt a given weight of iron, coke possesses advantages which permit of its use at even greater cost, and he recommends that in large casts, where iron of uniform temperature is required, a mixture of coal and coke should be employed.

V.—*LIQUID FUEL.*

The Oil Regions of Pennsylvania and New York.—The most important questions connected with the oil industry are those of oil supply and the possible ultimate exhaustion of the field. In order to illustrate these points, Mr. C. A. Ashburner* publishes a statistical chart and a map of the oil regions. The latter have a productive area of 364 square miles; the total production between 1859 and the end of 1884 having been 260,990,035 barrels of 42 gallons each. The irregular but steady decline in the daily production of petroleum from July 1882, when the maximum average daily production for any one month was attained (105,102 barrels), is now generally realised. The production for any one month or any one year may be increased very materially by renewed activity in drilling wells or by working over old territory, but such an increase can only be of limited duration, and there is nothing to expect but a progressive decline. In 1884 the total production was 22,732,209 barrels. In 1883 there were in the region 17,000 providing wells, the average daily production of which was 3·8 barrels. In July 1884 there were 21,844 producing wells, with average daily production of 3 barrels; and in July 1885 there were 22,524 producing wells, the average daily product being 2·5 barrels.

---

* *Transactions of the American Institute of Mining Engineers*, vol. xiv. pp. 419–428.

The Comparative Furnace Value of Coal and Petroleum.—In an experiment recently made in connection with the Henderson furnace at Boston, in which a petroleum vaporizer, actuated by the use of superheated steam, was connected with the gas inlet neck of the furnace, it was found that 25 gallons or 162·5 lbs. of petroleum were used per hour to melt 2-ton charges of soft steel, 240 lbs. of Westmoreland coal being required to be burnt per hour to attain equivalent results.*

VI.—*NATURAL GAS.*

The Geology of Natural Gas.—Mr. C. A. Ashburner † records a few general conclusions which have resulted from his own field observations, in connection with the Geological Survey of Pennsylvania, extending over a period of ten years. The oil and gas regions of Pennsylvania are one in a geological sense. The strata drilled through by the gas wells in the vicinity of Pittsburg, are practically the same as those of other oil districts lying at distances varying from 8 to 48 miles from that town. The rocks of the oil and gas regions lie nearly horizontal. The maximum dip is 69 feet per mile, the average dip being considerably less. The rocks which have so far been found to produce natural gas have a vertical range of 3000 feet of Carboniferous and Devonian strata. The principal gas horizons are:—the Venango first oil sand at Pittsburg, 1800 feet below the coal bed; the Sheffield gas sand; and the Bradford oil sand. It is believed that the gas is not indigenous to the sand-rock from which it is obtained, but comes from the decomposition of life-forms in the underlying strata; and is consequently obtained where the rocks are not jointed, and is not found where they are jointed. It is generally assumed that gas will be found most abundantly at the summit of an anticline. There are, however, notable instances in which gas has not been found in anticlines, but has been found in synclines.

The pressure under which the gas flows from the different wells varies greatly. In the Pittsburg district it averages from 100 to 200 lbs. per square inch. At Carnegie's works, nine miles from the well, the gas has a pressure of 75 lbs. per square inch. At the Bessemer Steel Company's works at Homestead, the recorded pressure is 60 lbs.

---

* *Iron Age*, vol. xxxvi. No. 20.

† *Transactions of the American Institute of Mining Engineers*, vol. xiv. pp. 428–439.

per square inch. The highest pressure recorded is 750 lbs. per square inch. The composition of the gas from different wells, or from the same well at different times, is found to vary slightly. According to recent analyses by Mr. S. A. Ford, the average composition at Pittsburg is as follows:—

Carbonic Anhydride.	Carbonic Oxide.	Oxygen.	Olefiant Gas.	Ethylic Hydride.	Marsh Gas.	Hydrogen.	Nitrogen.	Total.
0·6	0·6	0·8	1·0	5·0	67·0	22·0	3·0	100·0

One thousand cubic feet of natural gas is equivalent in heating power to 55 lbs. of Pittsburg bituminous coal.

In the city of Pittsburg alone, there are being supplied with natural gas 1500 dwellings, 66 glass factories, 34 rolling mills, and 45 other industrial establishments; 10,000 tons of coal being thereby displaced daily.

Natural Gas.—H. M. Chance * remarks that it has now been well established—(1.) that gas exists like oil in porous sandstone reservoirs; (2.) that the gas of the Pittsburg district is found in the sandstones (upper member of the group), yielding oil in Butler, Clarion, and Venango Counties; (3.) that the yield of any sandstone will depend upon the thickness of the porous portion of the rock, upon its porosity, and upon the pressure under which the gas exists in the rock.

The author shows that the theory that natural gas is present in a liquid form in the mother-rock is inaccurate, and he gives the following figures as representing the mean composition of the gas:—

	Per Cent.
Hydrogen	5·0 to 20·0
Nitrogen	1·0 ,, 12·0
Marsh gas	60·0 ,, 80·0
Ethane	1·0 ,, 8·0
Propane	0·0 ,, 2·0
Carbonic anhydride	0·3 ,, 2·0
Carbonic oxide	trace
Illuminating hydro-carbon	0·0 to 1·0

The author, by calculation, shows that with gas-bearing sandstone 30 feet thick, having a porosity of one-sixth, and under a pressure of 50 atmospheres, 1 cubic foot of the rock would retain 50 cubic feet of gas, or 1 square mile 7 billions of cubic feet. If this ratio holds good for the Pittsburg district, with a radius of 30 miles, it would yield 1981 billions of cubic feet of natural gas.

---

* *Iron Age*, vol. xxxvii. No. 12.

The average calorific value of natural gas is not yet accurately known, but experiments made at numerous works show that about 1000 cubic feet of the gas are equal to one bushel of ordinary coal, or about 26,000 cubic feet to the ton.

It is estimated that natural gas has already taken the place of a daily consumption of from 10,000 to 15,000 tons of coal. If this be increased to 20,000 tons, and if it is assumed that in practice 30,000 cubic feet of natural gas will be equal in furnace value to the ton of coal, the gas-wells of the Pittsburg district will be exhausted in about eight years. If, however, the actual pressure is equal to the maximum possible pressure, then the quantity of gas will be doubled, requiring at the above-mentioned rate twenty years for its exhaustion; but as the highest pressures hitherto observed have varied from 500 to 700 lbs. per square inch, the assumption of 750 lbs. as the average actual pressure is probably fairly accurate.

In a paper read at the Pittsburg meeting of the American Institute of Mining Engineers Mr. W. P. Shinn states that, according to the report of one of the companies supplying the city of Pittsburg, the supply of gas is drawn from 42 wells, situated in the Murraysville, Tarentum, and Washington fields, about 20 to 22 miles from the post-office. The mains and distribution pipes now laid are 1,773,662 feet, or 335 miles 4862 feet in length. The amount of coal displaced by this company's gas is about 10,000 tons per day.

A New Gas-Well.—The most powerful gas-well in the world is stated * to be one in Washington County, Pennsylvania. The rush of gas was originally so great that it was almost beyond control, and there was a constant fear lest the tubing, &c., should be blown to pieces; it was consequently determined to sink another well within 100 feet of the first, in the hope that the gas pressure would thereby be diminished. Instead of a 3-inch casing the new well was lined with 6-inch heavy iron pipe, which was carefully secured. At the end of less than sixty days from first starting the new boring, the depth of the first—the M'Guigan — well, 2238 feet, was reached, scarcely any gas being found. At the depth of 2250 feet the gas was struck, tools were blown out, and then the greatest gas-flow as yet observed in the Washington field took place. An effect on the M'Guigan well was immediately noticed; its roar diminished and its pressure became weaker; and it was finally screwed down, thus completing the experiment. By the screwing down of the M'Guigan well a still larger quantity of gas issued from the new one. In this way the pressure of the old well has been reduced to a safe point, while the flow of gas from the new well is now greater than it was originally from the old one.

---

* *Iron Age*, vol. xxxvii. No. 10.

Comparison of Natural Gas and Coal.—Mr. S. A. Ford, chemist of the Edgar Thomson Steelworks, publishes, in the *American Manufacturer*, some analyses of natural gas, together with calculations showing the comparison between its heating-power and that of coal. The calculations are of course theoretical in both cases.

One hundred litres of average natural gas will weigh 64·8585 grammes, thus:—

	Litres.	Grammes.	Calorics.
Marsh gas	67·0	48·0256	627,358
Olefiant gas	1·0	1·2534	14,910
Ethylic hydride	5·0	6·7200	77,679
Hydrogen	22·0	1·9712	67,939
Nitrogen	3·0	3·7652	...
Carbonic anhydride	0·6	1·2257	1,808
Carbonic oxide	0·6	0·7526	...
Oxygen	0·8	1·1468	...
Totals	100·0	64·8585	789,694

One thousand cubic feet of this gas will yield 210,069,604 calories, the number yielded by 57·25 lbs. of carbon. If coke contains 90 per cent. of carbon, 62·97 lbs. of coke are equal in calories to 1000 cubic feet of natural gas. Then if a ton (2000 lbs.) of coke costs 2·50 dollars, 1000 cubic feet of gas is worth 7·8 cents for its heating-power.

Taking as standard of comparison a coal slightly above the general average of Pittsburg coal, namely:—

Carbon.	Hydrogen.	Nitrogen.	Sulphur.	Oxygen.	Ash.	Total.
82·75	5·31	1·04	0·95	4·64	5·31	100·00

it is found that 54·4 lbs. of this coal is equal in its heating-power to 1000 cubic feet of natural gas, and at 1·20 dollar per ton of 2000 lbs., 1000 cubic feet of gas is worth for its calories 3½ cents.

A New Apparatus for the Perfect Combustion of Natural Gas in Furnaces.—Mr. E. J. Dashbach * has applied the principle of the Argand burner to natural gas. The apparatus has been introduced at several of the Pittsburg steelworks, and it is claimed that by its use the heaters are enabled to make their heats in one-third of the time formerly required—that is, in one hour instead of three hours. As the combustion takes place in the furnace, the stacks are not burned, and a considerable saving of gas is effected.

---

* *Engineering and Mining Journal*, vol. xli. p. 90.

VII.—*ARTIFICIAL GAS.*

Gas Producers.—In a paper read before the Institution of Civil Engineers, Mr. F. J. Rowan * stated that the investigations of the late Dr. Grouven, Mr. William Foster, and others, by directing attention to the nitrogen contained in coal, and to the large proportion remaining in coke and recoverable therefrom, have added to the advantages of the use of gaseous fuel the important consideration of the value of by-products which may be associated with its production. If any of the nitrogen existing in coal is to be recovered as ammonia, the employment of gas-producers of some sort becomes a necessity.

In the production of gas from coal and coke the following classes of apparatus have been devised and used :—

1. Retorts, heated externally, for distilling the hydro-carbons from coal apart from contact with air ; coke, as a refuse material, being withdrawn periodically. This is the ordinary form of plant in use in gasworks.
2. Generators, or producers, in which coal is consumed or converted into gas by combustion with access of air. The hydro-carbons are distilled in these appliances by means of the heat conducted or radiated from the zone of combustion, and the coke or fixed carbon is burned with air, first to carbonic anhydride, which is subsequently reduced to carbonic oxide by contact with the incandescent carbon.
3. Producers, in which the same result is arrived at, with the modification in the composition of the resulting gas due to admixture of steam with the air-supply.

In the two latter classes the producers may have either a grate with bars, or a closed hearth, and may consist of one or of two chambers ; in the latter case the distilling chamber may be heated partially or entirely from flues or passages on the outside ; the resulting gas is of the same composition in both cases, and must contain from 30 to about 60 per cent. by volume of nitrogen derived from the air introduced for combustion.

---

* *Minutes of Proceedings of the Institution of Civil Engineers*, vol. lxxxiv. pp. 3–113.

In one form of the apparatus of Class 3 (namely, Young & Beilby's), steam is used in excess, while the combustion of the coke is maintained at a comparatively low heat; as the primary purpose of this apparatus is not the production of good heating gas, but the securing of the nitrogen of the fuel as ammonia.

4. Apparatus in which incandescent coke or anthracite is used to decompose steam for the production of water gas, either continuously, by the use of retorts heated from the outside, and containing the carbon in contact with which steam is decomposed; or intermittently, by the use of generating chambers in which the carbon is first brought to a state of bright incandescence by an air-blast, and into which, secondly, steam is passed through the carbon, the air-blast being shut off; or the heat produced by the combustion of the carbon, or of gases from the generating chamber, is, in the first instance, stored up in brickwork, which, being made white-hot, is then used to decompose steam.

5. The author has recently proposed an apparatus combining the retort system of distilling the hydro-carbons from coal, with means for consuming the resulting coke or fixed carbon in an atmosphere of steam only, excluding air, and applying a sufficiently high temperature to prevent or minimise the formation of carbonic anhydride, the whole working together continuously and automatically.

The practical value of any example of these various classes depends upon the quality of the gas produced and the cost of production, a rough practical test of the efficiency of a gas-producer being afforded by the percentage of carbonic anhydride and nitrogen contained in the gas, and the volume of gas of a given temperature produced per ton of coal. An exception is made in such special apparatus as that of Young and Beilby, which must be tested by the yield of ammonia obtained per ton of coal.

All the trustworthy analyses of producer gases available, show that the gas from producers worked by internal combustion does not contain more than 45 per cent. (but as little sometimes as 26 per cent.) of combustible ingredients, having, according to the various authorities, a theoretical calorific intensity of from 1575° to about 2200°. Water gas, made by means of retorts or of intermittent apparatus with ordinary illuminating gas made by distilling coal, contains from 86 to 97 per cent. of combustible matter, with corresponding possibilities of producing high temperatures. Illuminating gas has, however, a higher calorific value than ordinary water gas, but not higher than the gas made in the apparatus of Lowe & Strong.

With reference to the advantage of using steam along with the air-supply in internal combustion producers, Mr. R. Schöffel has calculated, on the supposition that producers are worked at a minimum temperature of 1200°, that 85 parts of carbon are gasified by air when 12 parts are gasified by steam, and that 18·5 parts of steam are required for 100 parts of carbon. Mr. A. Wilson has shown that the mixture to produce 100 parts by weight of gas is, roughly—coal, 17·5; air, 79·9; and steam, 4·0; or that 100 parts of coal required 22 of steam. Allowing for the difference between coal and carbon, Schöffel's calculation is practically in accordance with Wilson's. It is, however, probable that, in the future, efforts will be directed towards the perfection of means of producing gas free from the dilution of the large quantity of nitrogen derived from an air-supply, as this system not only affords the means of obtaining a high temperature of combustion, but also tends to simplify furnace arrangements, rendering it necessary to heat the air only prior to combustion in them, and not, as at present, both air and gas.

Water Gas.—E. Blass* points out that when steam is passed over red-hot carbon, a mixture of carbonic oxide, carbonic anhydride, and hydrogen is produced, the proportion of the carbonic anhydride varying with the temperature at which the decomposition takes place. Thus, if the temperature is sufficiently high, no carbonic anhydride is produced, and this increases in amount with a diminution in the temperature of the reaction.

Steam passed over carbon at the temperature of about 500° C. is decomposed with the formation of carbonic anhydride and hydrogen, while at the temperature of about 1200° C. no carbonic anhydride results, but only carbonic oxide.

After considering the amount of heat required to produce the decomposition, the author passes to the consideration of the processes in use for the production of the gas, and he shows that in the first place there is always a generator in which the fuel is first raised to a high temperature by its partial combustion, due to a current of air being passed through it, and that then, the air being shut off, steam is introduced for the production of water gas, and that when the temperature falls too low air is again admitted and the same operations repeated.

---

* *Stahl und Eisen*, vol. vi. pp. 3–13.

When the temperature is raised by the partial combustion of the fuel by air, generator gas is being produced, so that the characteristic feature of the water-gas generator is that ordinary generator- and water-gas are produced alternately; and it is in the use to which this generator gas is put, the fuel that is used, and the method of introduction of steam and air, that the methods of construction of the various water-gas generators differ from one another.

In America anthracite is used in pieces about the size of eggs, and the gas so obtained is carburised for lighting purposes. This carburisation is effected by the addition of heavy hydro-carbons, and then heating the mixture to a high temperature. Various processes are in use for this purpose, but the gas so produced is apt to burn with a smoky flame, and if the temperature falls very low, some of the heavier hydro-carbons are occasionally deposited.

The three main methods are those of Lowe, of Tessié du Motay, and of Strong. In the first of these the carburisation is effected by passing a mixture of the generator gas and the vapour of naphtha, petroleum residues, or other suitable hydro-carbons through a highly heated regenerator.

In the second process the water gas is passed through a series of highly heated retorts into which naphtha, petroleum residues, &c., are introduced. In the Strong process the water gas is first passed through a hot regenerator, and is then mixed with the hydro-carbon and passed through a layer of red-hot coal.

The effect produced by mixing the water gas with the hydro-carbon at high temperatures is due, the author supposes, to the carbonic anhydride and undecomposed water vapour contained in the water gas decomposing at the high temperature of the regenerator, the hydro-carbon forming a source of carbon, carbonic oxide and hydrogen being also produced.

At Essen there is a water-gas plant on the Strong principle made by Schulz, Knaudt, & Co., and it is found that the fuel consumed is about 1·2 kilogramme of coke per cubic metre of water gas. On passing 1100 litres of such gas through a cooler, 24 cubic centimetres of water were collected, this representing 4 per cent. by weight of the gas.

An apparatus which works automatically, a drawing of which is given, has been attached to the furnace to prevent the blast entering the scrubber, and so producing there an explosive mixture.

The blast for the combustion of the coke enters the regenerator for ten minutes at a time, this being succeeded by the passage of steam for another five minutes, then air and steam again alternately. The production is from 250 to 300 cubic metres of water gas per hour, and the gas so produced has the following percentage composition:—

Hydrogen.	Carbonic Oxide.	Carbonic Anhydride.	Nitrogen.	Total.
50·0	41·0	4·0	5·0	100·0

A curious point in connection with the working of this furnace is the formation of silicuretted hydrogen, which is produced during the period at which water gas is being made, especially at the beginning, when it is free from water vapour and carbonic anhydride. The quantity formed is so considerable that it is sufficient to colour the water-gas flame a strong orange yellow. As the percentage of carbonic anhydride increases, the amount of silicuretted hydrogen present diminishes, it being decomposed into silica and hydrogen, the former forming white clouds and settling partly in the scrubber, partly in the gasometer, and partly in the purifying boxes. It has not been found possible to determine the actual amount of the silicuretted hydrogen, but it must be very small.

The experience gathered during the working of the apparatus described above has shown that it would be better to employ one of smaller size; and, in consequence, a new one that has been erected produces only some 50 cubic metres of water gas per hour.

This apparatus, and the method of working it, is described at length, and it is stated that, per cubic metre of water gas produced, it consumes 1·5 kilogramme of a coke containing 5 per cent. of water and 14·75 per cent. of ash.

The author stated the cost of a water-gas producing plant to be about as follows:—

(1.) A plant to produce 100 cubic metres per hour, consisting of two generators, a scrubber, purifiers, regulators, a 200 cubic metre gasometer, boilers, buildings, &c., &c., would cost about £1350. (2.) A plant to produce 500 cubic metres per hour would cost about £3000, and (3.) one to produce 1000 cubic metres £3500.

According to the construction of the apparatus used, the fuel consumption is at the rate of from 0·8 to 1·5 kilogramme per cubic metre gas produced, and the power required per cubic metre gas per hour is about 1-50th of a horse-power.

In the discussion on the paper the author stated that he was not aware whether water gas had been employed in the working of open-hearths, but that it was about to be tried for that purpose at Wittkowitz.

Water Gas at Essen.—At a recent meeting of the Society of German Engineers, a paper on this subject was read by O. Knaudt,* a member of the firm of Schultz, Knaudt, & Co., who recently decided to adopt water gas at their works at Essen. They were induced to do so by the results obtained at Birmingham by a Swedish engineer. The design used there consisted of a producing shaft with two regenerator chambers, into which the hot gases passed during the blowing-up period with air-blast, and which were used for superheating the steam. There was also a chamber used for heating the air employed in blowing-up. The shaft and chambers were all square in section and built in one block together, being all inside the same iron casing. A consequence was, that as soon as all the brickwork got hot the gases passed through it to a considerable extent, instead of following their proper course through the regular opening provided. The brickwork was rapidly consumed at the hottest part of the fire, no arrangement having been made either to protect it or to allow of its easy and rapid renewal. In designing the plant at Essen these mistakes were corrected; the shaft and chambers were built separate, each one with its own iron casing, and the hottest part of the producing shaft was protected from corrosion by a cooling ring with water circulation. In the first plant used at Essen the regenerator chamber for heating the air-blast was retained. As this has to be alternately full of air and of gas in the different periods of the process, danger of explosion was obvious; but the Swedish designer was supposed to have guarded against this in the mode of working the apparatus. It proved, however, that he had not removed the danger, for explosions did occur—some of them comparatively harmless, but finally one so severe as to cause the stoppage of the work altogether. The original apparatus had also a hopper for feeding coal dust in with the steam, as it had been believed that in this manner great advantages were obtained. This was not found to be the case during the work at Essen. For the movement of the different valves and dampers during the reversals of the apparatus there was a long shaft on to which the various connecting levers were keyed, and this part of the arrangement was also found defective in working. After the final explosion, which caused the stoppage of the plant, it was decided not to abandon the attempt, but to modify the apparatus. The regenerator for the air was abolished, the coal-dust hopper was removed, the reversing gear simplified, and proper close-fitting, water-cooled slide-valves, on the principle of engine-valves, were employed at

* *Zeitschrift des Vereins deutscher Ingenieure*, vol. xxix. pp. 800–801.

the point where gas and air pass alternately the same port. With these modifications the apparatus was again started, and has since never given trouble in any way.

VIII.—*COAL-MINING.*

Accidents in Mines.—The final report of the Royal Commission on Accidents in Mines was issued early in April. The Royal Commission was appointed about seven years ago, the members being Professor Warington W. Smyth, Professor Tyndall, Sir F. Abel, Mr. Thos. Burt, M.P., Sir W. T. Lewis, Sir George Elliot, and Mr. Lindsay Wood. The following are some of the leading features of their conclusions and recommendations:—

Ventilation.—At a large number of collieries the sectional area of the intake and return air-courses may be increased with advantage. Where furnaces are used, they should by preference be in connection with dry and deep shafts, and should be provided with dumb drifts. Where mechanical contrivances are employed, they should be placed under such conditions as will tend to insure their being uninjured by an explosion, and, if they are not provided altogether in duplicate, there should be at least an engine in reserve. The improved system of ventilation by "splits" and the shortening of the air-courses, as practised in the larger collieries, is a subject of great importance, and more general attention should be given to it. It would conduce greatly to safety if the system of carrying the intake air through two parallel drifts were introduced into workings likely to become extensive, and where mechanical haulage is intended to be employed. As regards safety to workmen, it is impossible to lay down general rules applicable under all circumstances. The facility for ventilation and other advantages attendant upon the "long-wall" system appear, however, to insure the working of coal with the least danger, wherever the system is applicable.

Falls of Roof and Sides.—The casualties due to falls of the roof and sides are much more numerous than those due to any other cause. In order to reduce their number, the observance of the following precautions is recommended:—

1. The maintenance of ample supplies of timber in localities convenient to the workmen. 2. The proper training of each miner to the best modes of timbering, and of otherwise protecting his working place.

3. The exercise of increased care on the part of the workmen in watching the roof, sides, and face, and protecting themselves in time. 4. The introduction, as far as possible, of arrangements with the workmen which will make it their interest not to avoid the labour of putting up the necessary timber for their proper protection. 5. The employment of special timbermen for the timbering of main ways, and also for the repairing as well as drawing of timber. 6. Preventing timber being left in the goaf of long-wall workings, which would have the effect of breaking the roof. 7. Driving the working places as rapidly as possible by shifts of an ample number of workmen in each face, and so reducing the risk of falls and exposing the least number of men to danger at any one time.

The coal-cutting machines, of which so many have been brought forward during the last twenty-five years, are, in numerous instances, ingenious and effective, but cannot yet be accepted as a practical success. Recently suggestions have been made for the use of steel props or supports where timber is liable to perish quickly.

Miscellaneous Accidents.—The practice in some collieries in South Wales of boys running in front of the horses and trams should be prohibited.

Fire-Damp.—In working fiery seams at great depths, abnormal discharges of gas must occasionally occur, yet they may be successfully met by ample ventilation, good discipline, and efficient lamps.

Colliery Warnings.—Reliance should not be placed on the issue of meteorological warnings. Such warnings can at best only convey very imperfect information, which, moreover, may sometimes be dangerously misleading.

Coal-Dust.—The disastrous effects of fire-damp explosions in coal mines are almost always aggravated and extended by the existence of coal-dust in dry mine workings and roadways. A gas explosion in a dry mine, even if only of a comparatively trifling nature, will raise and inflame coal-dust existing at the seat of the explosion or in the vicinity; the flame attending the explosion will be thereby increased, and carried to more or less considerable distances, and may thus become communicated to any accumulations of explosive gas mixture which may exist in goaves or other lurking places at a distance from the seat of the original gas explosion. The application of water to the laying of dust in roadways has been applied here and there with some amount of success, but the effective adoption of such a measure in or near the working places is in some instances attended with practical difficulties.

Unless very copious watering be resorted to, it would be ineffectual in guarding against the dangers arising from the firing of powder-shots in dry and dusty workings where the air may contain some small proportion of fire-damp. The employment of hygroscopic or deliquescent salts in conjunction with water has not been found a trustworthy means of maintaining dust in a safely moist condition. The dangers which attend the firing of powder-shots in dry mine workings where dust exists in abundance, and where the air may contain even only a small proportion of fire-damp, cannot therefore, with our existing knowledge, be effectually guarded against except by combining the removal of dust as far as practicable with very copious watering.

Gunpowder and other Explosives.—The use of gunpowder for blasting in dry coal mines should be prohibited. The available alternatives are the lime cartridge, mechanical appliances, and the high explosives (dynamite, gelatine-dynamite, tonite).

Precautions in Blasting.—The following instructions should be observed:—1. That all work involving blasting in mines should be intrusted only to experienced workmen. 2. That, in order to lessen the risk from blown-out shots, particular care should be taken that each shot should be assisted by under-cutting and nicking or shearing whenever it is practicable. 3. That the tamping should consist of very damp or non-inflammable material. 4. That, where strong tamping is needed, the compression of air at the bottom of the hole should be avoided by pushing in the first part of the tamping in small portions. 5. That, where safety lamps are used, and powder is employed, the shots should be fired only by specially appointed shotmen, who, before firing the shots, shall satisfy themselves that the foregoing instructions are observed, and shall also satisfy themselves, by carefully examining all accessible contiguous places within a radius of twenty yards of the shots to be fired, that fire-damp does not exist to a dangerous extent.

Mode of Firing Shots.—The employment of the ordinary miner's fuse should not be permitted in any mine where the exigencies of safety dictate the exclusion of powder, and the substitution for it of high explosives in conjunction with water. Similarly, no mining fuse should be allowed to be ignited by any source of fire which must come into contact with the atmosphere of the mine. Electrical arrangements for exploding shots should be encouraged as much as possible.

Lighting and Safety Lamps.—Appliances now exist by which very small proportions of marsh gas in air may be readily detected. These can be used for examining the atmosphere of a mine. With Liveing's indicator, gas present in the air can be estimated with sufficient accuracy for all practical purposes, even when the proportion is as low as 0·25 per cent. Maurice's indicator is also capable of giving accurate measures of the proportion of gas, and is very portable, but the time required in taking an observation with the instrument in its present form seems to preclude its practical application.

The Commissioners arrive at the following conclusions:—1. That it is most important that all mines should be carefully examined by means of indicators capable of detecting as small a proportion as 1 per cent. of gas; such examination to be made before the commencement of each day shift, and, in case of an interval, also before the succeeding shift. 2. That in all DRY mines where the air may be laden with coal-dust, and where fire-damp is known to be given off, the Secretary of State may require safety lamps to be used, unless the owners and workmen of such mines prove, to the satisfaction of a court of arbitration to be appointed by the respective parties, that less liability to accident generally will be involved by the working of the mine with open lights than by the use of safety lamps. It should be a special instruction to such court that the circumstances of each mine be taken into consideration with reference to the following points:—(*a*) The mode of working; (*b*) the nature of the coal seams, of their roofs and floors, and of the adjacent strata; (*c*) the proximity of the seams to each other; (*d*) the emission of gas from the seam and the liability to outbursts of gas from the coal, roof, or floor; and (*e*) the order of working the seams of coal.

For the system which prevails in some places of working with mixed lights—that is, with open lights and safety lamps intermixed in the same set of working—there is no justification, and this practice should be strictly prohibited.

It is shown that the improved ventilation of the mines has rendered the Davy and Clanny lamps absolutely dangerous, and the Stephenson lamp also in a large measure. The Davy lamp becomes unsafe with a current, the velocity of which is 400 feet per minute; the Clanny, with a velocity of 600 feet, and the Stephenson with a velocity of 800 feet. The currents sweeping long wall-faces have, however, very often higher velocities, and in main air-ways current velocities approaching 2000 feet per minute are recorded, and considerably higher velocities are encountered at regulators and in narrow places, or when large falls occur. The four lamps in which safety in a pre-eminent degree is combined with simplicity of construction and good illuminating power are Gray's, Marsaut's, Evan Thomas's No. 7—latest pattern, and the bonneted Mueseler; but the lamps of Hann, Morgan, Purdy and Soar are also highly spoken of. These lamps should be effectually locked, for though the practice of opening the lamps underground is much less prevalent than it was at one time, it should be put out of the power of the miners to tamper with them and thus probably lead to an explosion. The simplest and most effective means of preventing lamps from being surreptitiously opened is a lead plug firmly riveting the lamp case and the oil vessel, this plug being stamped at each end with letters or marks varied from day to day. The Commissioners have made experiments with more than 250 lamps, English, French, Belgian, and German, namely, 456 experiments at Garswood Hall, 553 at Llwynpia, and 763 at Woolwich, in all 1752 experiments, and the Blue Book contains not only drawings and details of each lamp, but a record of each of the experiments. The Commissioners recommend the use of an illuminant for lamps of a vegetable or animal oil mixed with about one half of its volume of a petroleum oil of safe flashing point. The use of petroleum spirit or benzene is attended with some danger.

Electric Lighting.—The great progress recently made in the construction of portable electric lamps affords promise of a speedy utilisation of such lamps to an important extent in coal mines.

Safety Hooks.—The safety hooks at present available may have contributed to prevent fatalities from overwinding; the best appliance for the purpose, however, is an automatic steam break attached to the winding gear.

Ambulances.—Mines should be required to provide an ambulance, and arrangements should be made for the establishment of centres in mining districts where appliances for succour and exploring purposes should be maintained in an efficient condition.

Shaft Sinking by Means of Compressed Air.—This method has recently been applied at the Marie Colliery at Höngen, in Prussia. for sinking an iron tubing-shaft 19 feet 8 inches in diameter, through a bed of quicksand 37 yards thick.* The work was carried on at a pressure of 3·2 atmospheres. The men worked eight-hour shifts. During this time the workmen were twice let down and pulled up, each operation lasting half an hour. For the remainder of the time, two and a half to three hours, they worked hard in the compressed air The temperature in the working-chamber did not exceed 11 to 13° C. The work lasted 228 days, and had no detrimental influence on the health of the workmen.

---

* *Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate*, vol. xxxiii. pt. 3.

Poetsch's System of Sinking Shafts through Water-Bearing Strata.—M. F. Lebreton[*] gives a detailed account of this system. The method consists simply in freezing the material about the space to be excavated, thus converting it temporarily into a solid wall, which permits the excavation to be made.

The author gives the following table, showing the comparative cost of the various methods of sinking through water-bearing strata:—

System.	Colliery.	Cost per Foot.			Total Depth in Feet.	Strata Passed Through.	Time in Months.
		£	s.	d.			
Triger	Havré	888	19	0	124	Sand and chalk	48
Triger	La Louvière	98	3	0	42	Quicksand	2
Chaudron	St. Waast	37	8	0	321	Chalk marl, sand	29
Chaudron	Lescarpelle	20	17	0	331	Sand, chalk	11
Chaudron	St. Barbe	33	3	0	180	Clays, marls, sand	18
Chaudron	St. Marie	12	9	0	344	Clays, marls, sand	13
Chaudron	Rothausen	38	11	0	338	White marl	25
Poetsch	Archibald	17	16	0	131	Quicksand	...
Poetsch	Emilia	25	16	0	140	Sands	8
Poetsch	Wasterhausen	30	0	0	98	Sands, boulders	6

Temporary Iron Lining for Shafts.—The Victoria circular shaft of the Gerhard Colliery, Saarbrücken, 935 feet in depth, has been lined with brickwork, iron rings being used as a temporary support. The rings consisted of 4 segments, and were placed 5 feet apart. The walling was commenced at a depth of 82 feet 2 inches, the provisional lining being removed as the walling advanced. As soon as the walling of the first length was finished up to the surface, the sinking was continued, a bed of rock being left for the brickwork. Beneath this, the section gradually widened to the proper size of 17 feet 9 inches. The walling was 1 foot 7 inches thick. At a depth of 164 feet 5 inches the second crib was placed, and the ground walled up in exactly the same way as the first, the bed left being cut away. In this way, the sinking was carried down 820 feet. The provisional ironwork of one length was used again in the next below.*

---

[*] *Annales des Mines*, vol. viii. pp. 111-171. Compare this Journal, 1883, p. 826, 1884, p. 257.

Watertight Shaft Walling with Stone Cribs.—At the Government colliery at Osterwald, in Hanover, sandstone rings made in 10 segments have been used for a deep sinking instead of cast-iron cribs. The joints are wedged with wood. These stone cribs are considerably cheaper than cast-iron ones.†

New Safety Catch for Pit Cages.—At a meeting of the Manchester Geological Society, Mr. C. F. Clark ‡ described a new safety catch for pit cages, invented by Messrs. Brown. This new safety catch had been brought under the author's notice some months ago, and he had arranged for its being attached to a pit cage. The cage was a single deck, carrying three boxes, in a shaft 420 yards deep, working on three conducting wire guides, 1⅛ inch diameter, firmly fixed to cross bars on the head gear. The guides, which consisted of seven strong wires, ⅜ inch diameter, were fixed, two on the inside angles of the cage, and one on the outside, in the centre of the cage. The total weight of the loaded cage was 60 cwt. There had been three or four experiments to test the invention by means of a knock off hook, both with the empty cage and with it loaded, and on all occasions the apparatus acted instantly, the cage not dropping more than six inches when loaded. The cage had been at work about five months, and during that time they had had no hitch nor trouble with it. In adopting the catches care should be taken to see that the guide rods were of sufficient strength to carry the full load of the cage, and that they were securely attached to the head gear.

The new safety catch is a contrivance for arresting the descent of the cage in shafts which are provided with round wire guide rods, extending from the top to the bottom of the shaft. On each side of the cage, levers are placed, turning upon pins secured to the sides of the cage. The ends of the levers nearest the guide rods are provided with hinge joints, from which extend upwards suitable rods having rollers with flat circular surfaces in order to insure a more perfect and effectual grip on the guide rods and inclined planes, the latter being suitably fixed to the sides of the cage. The opposite ends of the levers are each secured by a hinged joint to connecting rods, which are joined together above the cage to the stride chains or winding-rope. When the cage is suspended, the rollers are drawn away from the guide rods and the inclined planes, the whole weight of the cage being supported by its own tie rods or chains which form the connection between the cage and the rope; but in the event of the rope or any of the connections breaking, the safety catch comes into operation by the suspended ends of the levers falling, the opposite ends consequently rising with the rollers into the inclined planes, and gripping the guide rods, whereby the cage is held by its own weight acting upon the rollers in the inclined planes, and is prevented from falling down the shaft. To ensure the levers operating quickly, springs are employed for pressing the levers so as to force them against the guide rods immediately upon the breakage of the rope.

---

* *Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate*, vol. xxxiii. p. 223.

† *Ibid.*, vol. xxxiii. p. 224.—*Minutes of Proceedings of the Institution of Civil Engineers*, vol. lxxxiii. p. 516.

‡ *Transactions of the Manchester Geological Society*, vol. xviii. pp. 515–518.

New Safety Cartridge for Coal Mines.—A new safety cartridge has lately been introduced in Germany by Dr. Kosmann.* Its action depends upon the rapid liberation, in the bore-hole, of a large quantity of hydrogen, the pressure resulting from which forces the coal or rock asunder. The hydrogen is liberated by means of the action of sulphuric acid upon very finely divided metallic zinc. For this purpose is employed the bluish-grey powder which forms in the condensers of zinc distillation furnaces. There is a certain amount of oxide mixed with the mass, but for all practical purposes it may be considered as metallic zinc. The cartridge consists of a glass cylinder, narrowing to a neck, and being also contracted at a point below the neck, so that the cylinder is divided into two portions, communicating through a contraction, the opening of which is 8 to 10 millimetres. The contraction is so placed that the two parts of the cylinder are to one another in cubic capacity as 1 to 4, the smaller part being near the neck of the cylinder. The lower, or larger division, is filled with sulphuric acid. The contraction is then closed, and in this condition the cylinder is handed over to the miner. The bore-hole is well clayed over inside in order to close any cracks through which gas could escape. The upper part of the glass cylinder is now charged with the zinc powder, and an iron rod is laid in, passing through the zinc and resting upon the stopper in the contracted part of the cylinder. The neck of the cylinder is then tightly plugged with clay, and it is laid in the hole, which is then also well tamped with clay, the iron rod passing through both these clay stoppings, and projecting some little distance beyond. In order to fire the shot, the miner strikes the iron rod with the hammer, so as to drive in the stopper in the contracted part of the cylinder, or to break the glass at that part. In either case the acid at once runs in among the zinc powder and a very rapid evolution of hydrogen takes place. The iron rod is not uniform in thickness, but conical, being thicker towards the outside, and this increase of thickness is considerable, so that when the rod is driven in, it keeps tight in the clay stoppings, and prevents any escape of gas. A cartridge 180 millimetres long and 25 millimetres in diameter, taking a charge of 50 cubic centimetres of acid and 12 grammes of the zinc powder, will give rise to an evolution of gas equal to 3·37 litres at ordinary barometric pressure; and the compression of this volume of gas into a space of 90 cubic centimetres means a pressure exerted on the sides of the hole equal to some 37 atmospheres.

---

* *Berg- und Hüttenmännische Zeitung*, vol. xlv. p. 200.

Dr. J. Macnab * shows that the action of this cartridge is too slow for working coal.

On the Use of Water Cartridges.—In some experiments made at the collieries of the Bonifacius and Zollverein Associations, in the case of eight shots in which the dynamite was surrounded by water, part of the bore-holes being in rock, and the remainder in coal, fire was observed on each occasion, this being occasionally accompanied by showers of sparks, thus proving that the use of water is not a sovereign specific under all circumstances for the prevention of explosions due to shot-firing.†

New Explosives.—Hellhoffite consists either of dinitro-benzene and nitric acid in the proportions by weight of 1 : 1·5, or of mononitrobenzene and nitric acid in the proportions 1 : 2·5. It is a dark-red to brown-coloured liquid, and is used after absorption by kieselguhr or some other absorption agent.

According to the experiments made at Neunkirchen by H. Margraf,‡ kieselguhr-hellhoffite possessed the following advantages over kieselguhr-dynamite:—1. It is cheaper. 2. It may be stamped harder when placing it in position in the bore-hole, and consequently may be brought much closer to the sides. 3. It does not explode coal-dust and fire-damp if the percentage of marsh-gas does not exceed 10, while an explosion is, under similar circumstances, produced by dynamite with 4·5 per cent. 4. The hellhoffite does not sweat out of the cartridge, and if it did there would be no danger, as the liquid cannot be exploded by concussion. 5. It produces a greater percentage of large coal. 6. The gases produced by the explosion are not unpleasant to breathe.

---

* *Engineering*, vol. xli. pp. 627–628.

† *Glückauf*, 1885, No. 90.

‡ *Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate*, vol. xxxiv. pp. 59–72.

Unfortunately, however, hellhoffite is subject to decomposition and its manufacture has been abandoned, its place being filled by another explosive—carbonite—possessing all the relative advantages of hellhoffite without being subject to decomposition. It, also, contains nitro-benzene, is of grey-brown colour, is as plastic as dynamite, and has the specific gravity 1·3.

The Walcher Coal-Mining Machine.—This hydraulic coal-getting machine is intended to replace blasting in collieries. The machine, according to Eugen, Ritter von Wurzian,[*] consists of two parts: the coal-getter, which is placed in a bore hole in the coal, and a hydraulic press cylinder with pump. The details of construction are described at length by the author, drawings of the different parts accompanying the paper.

To use the machine, the coal is first holed to a depth of one yard, and holes bored in the face, one bore hole being sufficient for 5 to 10 yards of face. The bore hole is 4½ inches in diameter and 39 inches deep. A modified Lisbeth boring machine is employed, the hole being completed in ten minutes.

The machine has been employed with success in the Archduke Albrecht's collieries in Teschen. The advantages claimed for it are, that it may be employed in fiery mines without endangering the lives of the workmen, and that a larger proportion of round coal is obtained. The apparatus is so portable and powerful that it fulfils all the requirements for getting coal.

The Cost of Haulage in Anthracite Collieries.—Mr. A. W. Shaefer publishes[†] the following figures, showing the relative cost of haulage in the Kalmia Colliery, in the Schuylkill anthracite region. The results were obtained from the superintendent, and are based on the work of 1882, in which the output of the colliery was 201,000 tons. The length of the main roadway is about three miles, principally in a straight line, the round trip thus being six miles long. Three Baldwin locomotives, inside connected, are in constant use. The following is the record:—

---

[*] *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxiv. pp. 283-287.

[†] *Proceedings of the Engineers' Club of Philadelphia*, 1885, p. 150.

	One Locomotive.	Sixteen Mules.
Time of trip	1h. 40m.	...
Haul of 2½-ton trucks per trip	18 to 26	...
Haul of trucks per day	133	133
Average steam pressure	105 lbs.	...
AVERAGE EXPENSE PER DAY.	£ s. d.	£ s. d.
Coal, 1097 lbs.	0 5 7½	...
Oil, waste, packing, &c.	0 2 11	...
Repairs and renewing (estimated)	0 2 6	...
Wages, engineer, boy to switch, &c.	0 13 10½	...
Feeding, shoeing, repairs to harness, depreciation and death, at 3s. 5½d. per day	...	2 15 4
Drivers, one for six mules, at 7s. 1d. per day	...	0 18 10½
Oil and cotton	...	0 1 8
Total expense per day	1 4 11	3 15 10½

Transmission of Power by Steam.—Messrs. Liddell and Merivale * describe the mode of supplying power 1294 yards in-bye by means of steam from a boiler at bank at Broomhill Colliery. Although this distance in-bye is very great, the crookedness of the rolleyway, and the surplus boiler power at hand, seemed to indicate that steam was the most practical mode of transmitting the power. It is taken at 35 to 38 lbs. pressure, through 5-inch cast iron pipes, 19 yards to the shaft, and 27 fathoms down the shaft. Here is placed one of Tangye's 5-inch steam traps and separators, which, when the engines are running, delivers about 9 gallons of water per hour. The pipes are covered with Wormald's composition, and then coated with felt and lead. There are two expansion joints; one placed horizontally between the boilers and the shaft, and the other vertically at the top of the shaft. The 5-inch steam pipes are then taken a further distance of 269 yards, with a vertical fall of 44 feet, to a receiver 6 feet long by 3 feet diameter. Near this receiver is placed a combined hauling and pumping engine, 12 inches in diameter by 2-feet stroke. The pressure of steam here is 32 lbs. The engine hauls 120 tons of coal per day, up a bank 101 yards long, rising 3·12 inches per yard;

---

* *Transactions of the North of England Institute of Mining Engineers*, vol. xxxv.

and 70 tons of coal per day up another bank, situated about half a mile further in-bye, 399 yards long, rising 3·35 inches per yard. It also deals with a constant feeder of 13 gallons per minute, which it forces a distance of 219 yards to a rise of 34 feet, through 4-inch pipes, by means of a double-acting pump, 6 inches in diameter by 1 foot 6 inches stroke. From the receiver, a range of 2½-inch wrought iron pipes is carried a further distance of 952 yards, with a vertical fall of 101 feet, to the in-bye pumping engine, where there are two of Tangye's 4-inch steam traps. The engine is a single cylinder horizontal engine, 8 inches in diameter, by 1-foot stroke, geared 3 to 2 to a Warner's three-throw single-acting ram horse pump; each ram is 4 inches in diameter by 1-foot stroke. The pressure of the steam is 25 lbs. The engine works for 6½ hours out of the 24, with a constant feed of 39 gallons per minute.

Official Regulations for the Management of Fiery Mines in Prussia.—Mr. M. Walton Brown* has published a translation of these regulations. The first division describes those mines to be fiery in which fire-damp has been found during the last two years, and permits independent divisions of workings to be considered as separate mines. Fiery mines, in all cases, must have two entrances—one for the entry and the other for the exit of the air.

The second division, on ventilation, provides for mines being divided into districts independently ventilated. The exclusive use of natural ventilation, and ventilation by means of boiler chimneys, is inadmissible, and the ventilation caused by furnaces is only allowed when these furnaces are fed with fresh air. Open fire kibbles are forbidden.

The quantity of air is regulated, and must consist of 53 cubic feet per ton of coal drawn daily. If this quantity is not sufficient to reduce the estimated fire-damp to 1½ per cent. of the general current, it must be increased. If the proportion of fire-damp and carbonic anhydride in the return air does not exceed 1½ per cent., the quantity of fresh air may be reduced to 35 cubic feet per ton of coal worked; but in all cases the quantity must at least amount to 70 cubic feet per workman. The escape of gas from old workings must be prevented either by hermetically sealing or by the ventilation of those workings. On the ventilation being stopped, or suffering serious disturbance, the workmen must be withdrawn at once, and shall only return to their work when the removal of the danger has been proved. As soon as any part of the workings is found to be dangerous from the presence of gas, the workmen shall fence off the dangerous part and leave it, warn their comrades, and report to the first official they meet.

---

* *Transactions of the North of England Institute of Mining Engineers*, vol. xxxv.

The third division applies to blasting; powder and slow-acting explosives are forbidden in fiery mines, where only rapidly-acting explosives, such as dynamite, are allowed; and the use of dynamite is prohibited when more than 3 per cent. of gas can be detected by the ordinary safety-lamp. Twelve yards from the shot-hole there must be a total absence of gas before the shot is fired; and stemming holes with coal-dust is forbidden.

The fourth division deals with lighting. The use of naked lights in fiery mines is forbidden, and only safety lamps or incandescent lamps are allowed. In the intakes, however, open lamps may be used in the shafts and their approaches.

The last division indicates the nature of special regulations for the administration of each mine, which have to be sent for the approval of the State.

The Influence of Pressure on the Escape of Fire-Damp.—C. Hilt * reports to the Prussian Commission on Fire-damp, that the experiments instituted by the Commission show that a rise in the barometer is always accompanied by a diminution, and a fall by an increase, in the percentage of marsh gas and of carbonic anhydride escaping from coal; the time which elapses between the rising or falling of the barometer, and the time when its influence on the escaping gas becomes evident, is never more than one day. In the experiments instituted it was found that the percentage of fire-damp was, on the average, 9 per cent. greater with a falling than with a rising barometer, the quantity of gas present remaining constant when the barometer was steady.

Carleton's Fire-Damp Indicator.—This apparatus, invented by by Mr. H. G. Carleton, consists of a pair of balances, each having at the beam a receptacle containing a given quantity of hydrogen gas; the receptacles being duly counterbalanced. The moving parts of the two instruments are electrically connected; and, when properly adjusted, any motion of one balance will instantly affect the balance of the other instrument, no matter how far apart the instruments may be situated.

---

* *Zeitschrift für das Berg-, Hütten-, und Salinenwesen im preussischen Staate*, vol. xxxiv. pp. 72–90.

Thus one instrument may be placed within a drift of the mine and the other in the superintendent's office. Should an inflow of fire-damp occur the beam of the balance will instantly turn, carrying information to the office showing the degree of change in the atmosphere of the mine. A detailed account of the construction and adjustment of the instrument is given in the *Engineering and Mining Journal.**

Portable Electric Lamp for Mines.—Mr. Joseph W. Swan † has devised a portable electric safety lamp for miners, in which the lamp and the supply of electricity to it are combined in one apparatus. The lamp is capable of giving during 10 or 12 hours two or three times the light of a common safety lamp. On first lighting it gives the light of 2 candles, and after 10 hours about 1½ candle. As in the lamp invented by the author four years ago, the light comes from a filament of carbon, hermetically sealed in a small tube, and this tube is protected by a bull's-eye of glass, so strong as to be practically unbreakable. The current necessary to render the filament incandescent is generated by secondary cells contained in the case. For regular mine working these are composed of lead and lead oxide. Another kind of cell can be used, composed of zinc and lead oxide, with a special view to the occasional employment of the lamp for exploration in vitiated air. This is a primary cell, and only requires filling with liquid to make it ready to give light. It will sometimes be convenient to have a duplicate lamp within the bull's-eye, with a switch connection to enable either, but not both, to be lighted, so that in case a lamp should fail the miner will not be left in the dark. The writer hoped to have been able to show a fourth modification, in which there are only two cells, instead of seven, to light a lamp. By this arrangement the weight is diminished to between 5 lbs. and 6 lbs. The weight is proportional to the light yielded and the time during which it is kept up. By taking from the electric lamp as small an amount of light as the ordinary safety lamp gives, its weight need not much exceed that of the heavier lamps in common use. Believing that a good light was the most important point to be gained, after safety, the electric lamp shown had been constructed to give two or three times the light of the ordinary lamps, and consequently it was heavier; in fact, weight was made subordinate to light; but it is hoped that the weight and size of the present lamp will not be found unhandy. The apparatus could have been made much lighter if it had been permissible to employ a primary battery instead of a secondary one; but it appears to be only allowable to use a primary battery to meet sudden emergencies, and in those cases where there is no dynamo and no regular system in operation for charging secondary batteries. A secondary battery such as the author has adopted can be charged with even less trouble than attends the trimming of an oil lamp. It is only necessary to insert a couple of wires from an electric main into the charging sockets of the battery, and to leave it there from the time the lamp is handed in at the end of a shift until it is wanted again, twelve or fourteen hours after. Hundreds of lamps can be charged at a time in this way, and at very small cost. An engine developing an effective five-horse power and a dynamo electric machine, correspondingly small, would suffice to charge 300 lamps at one operation.

---

* Vol. xli. p. 265.

† *Transactions of the North of England Institute of Mining Engineers*, vol. xxxv. pp. 51-64.

Large Output of Coal.—Some years ago 1050 tons of coal were drawn from the Manvers Main Colliery in a single working day, and up to a recent date that was a "record" in coal-mining. On November 13, 1885, however, at the Rockingham Colliery, Birdwell, 1144 tons were brought to bank from one shaft between 6 A.M. and 3 P.M. The shaft is over 300 yards deep, and four tubs are drawn in each cage.*

At the No. 2 shaft of the Excelsior Coal Company's mines at Excelsior, Iowa, during a recent ten hours' run, there were mined, screened, and loaded out of one shaft and over one pair of scales 1727 tons of lump coal; whilst the total of lump and nut together would not be much less than 2000 tons for the total day's output. This is stated to be the largest ten hours' output of soft coal on record in the United States.†

IX.—*COAL-WASHING.*

Theory of the Apparatus Employed for Washing Mineral Substances.—A. Badoureau ‡ shows that the various forms of jigging machinery, ore-dressing machinery with ascending current, percussion tables, Rittinger tables, the Bazin coal-washer, &c., are all based on the following principle:—A mineral particle placed in water, at rest or in motion, either introduced into the midst of the liquid or supported upon a solid base, describes a movement differing according to the size and density of the particle. It is thus possible to separate mineral particles according to their density, provided that only particles of nearly equal size are treated simultaneously.

---

* *Iron and Coal Trades Review*, vol. xxxi. p. 717.

† *Engineering and Mining Journal*, vol. xli. p. 267.

‡ *Annales des Mines*, vol. vii. pp. 521–534.

The author discusses successively the following points:—Deposition in water passing in a horizontal direction; deposition of a particle placed at rest a little above a horizontal table in a weak current of water; movement produced on a table by a current of water; movement given to a particle in water on a table by means of percussion; movement given by water circulating on an inclined table, with or without percussion; formation of the particles on a sieve into layers by the action of the water; and, lastly, movement in a spherical vessel full of water, and revolving around a vertical axis.

The Artois Coal-Washers at the Graissessac Mines.—M. Simon * gives the following details regarding the Artois coal-washers erected at the Bousquet Colliery of the Graissessac Company:—The Bousquet coals in jigging-machines give a large proportion of small coal, the proportion sometimes being as much as 20 per cent. By means of the Artois washing-machines this small coal is now utilised; 32 to 35 per cent. of the small coal formerly wasted being now recovered. The installation consists of a basin about 1 cubic metre in capacity, where the large particles of pyrites and shale, from the clarifiers, are deposited, and are shovelled out every evening. A wooden pointed trough, 750 litres in capacity, regulates the admission of material to the washers. Two shoots with sluices at the bottom of the trough regulate the quantity of water to be brought to each washer. The washed coals, sized, are placed in a small wooden labyrinth by means of a shovel of perforated metal, made for the purpose. They contain 10 to 11 per cent. of ash, and are used for coking or for the manufacture of patent fuel. Eight to ten per cent. of the total mass escapes into settling-basins, from which the feed-pump takes the water required for the jigging-machine. The coal from these basins contains 16 to 17 per cent. of ash, and is used for heating steam-boilers. The total produce is thus 41 to 43 per cent. The mean percentage of ash is 68 to 70 in the shale deposits, notwithstanding the large quantity of pyrites present. One washing-machine easily treats 25 tons of very impure material in 11 hours. It would easily wash 32 to 35 tons of fine coal

---

* *Comptes rendus mensuels de la Société de l'Industrie Minerale*, 1886, pp. 6–7.

The two washers and the feed-pump require about 5 horse-power. The whole installation is under the supervision of a lad of fifteen.

Improvements in Screening Arrangements.—Mr. A. H. Leach* describes the screens in use at the Brinsop Hall Collieries. In 1882 the state of trade and increasing competition induced the Company to improve their method of screening coal. Under the old system the coal had to be raked down the screen, and the loose pieces of dirt picked out of the shoot itself. This system caused a good deal of slack in the waggons; it was also very laborious and inefficient. In order to obviate the necessity of using the pick in the coal waggon, and to spread the coal over a larger area, so as to give plenty of cleaning room, belts have been put up on which the coal can be cleaned; steel-wire belts being preferred to those made of hemp or cotton. There are two reasons for this preference. (1.) Because the hemp or solid belt would carry the slack made in chipping on to one round-coal waggon, whilst with the wire belt the slack would pass through into a shoot beneath. (2.) It was thought the wire belt would stand the constant chipping better than other kinds of belting, and would not be affected by damp weather.

Experience has shown that the dimensions of the wire should not be less than the following:—Cross wires, 4 B.W.G.; longitudinal wires, 9 B.W.G. The mesh of the belt is 1½ inch by ½ inch, and width 4 feet. On each side, and running the length of the belt, is a plank fastened by brackets, on which a portion of the chipping is done. The slack which falls through the belt on to the shoot, and so on to the waggon, is a very small quantity. The coal, after passing over the belt, drops on to a screen, in which the cobbles are taken out, and thence into the round-coal waggon. After these belts were erected it was found that two hands were still required to rake the coal down the slack-screen on to the belt, for the reason that if the screen were made of such a gradient that the coal would run by gravitation, the slack would not be taken out thoroughly. In order to save this labour a shaking-screen or riddle was put up; but this did not answer, and the present arrangement of a movable screen has been substituted. This consists of two sets of bars, one of which is fixed and the other movable, these being arranged alternately. Both sets are fastened together at the bottom end by means of a rod, which runs through holes drilled at the end of each bar, and rests on a piece of angle iron running across the screen and fixed by a strap bolt in each side. At the upper end the fixed bars are bolted down to a bar of iron, which, like the angle iron, is held in its place by two straps. The movable bars are longer than the fixed ones, and also bolted on to a bar of iron. This bar is turned at each end so as to admit of a pulley 3 inches in diameter, which rests on a lever, thus giving motion to the screen. The upper ends of the movable bars are made shallower, so as to admit of their dropping down about half an inch below the top of the fixed bars. The throw of the eccentric is 8 inches, and the lever is so arranged as to give a stroke of 2½ inches to the moving-screen at its upper end, raising it about 2 inches above and allowing it to drop half an inch below the fixed bars. The space between the upper length of the screen and the movable portion is taken up by a plate about 14 inches in width, which works on a hinge at each end. The screen gate is fixed just above this door. This arrangement has been in use some time, and is working in a perfectly satisfactory manner; there is not the slightest oscillation in the head-gear, there is no breakage of the coal in the screen, and it saves the wages of two hands. What are termed dirt-belts have now been added to each screen; these were made at the colliery, of three old flat hemp ropes laid side by side and fastened together by means of rivets, and joined together at the ends by iron hinges. All the dirt or inferior coal is thrown by the screeners as it was picked off the coal-belt on to these dirt-belts, where it is again sorted; the good coal is put down a trough into the main coal-screen, the remainder passing on to the front, where it is divided, the dirt going down a trough into boxes, and the inferior coal down a shoot in front into carts.

---

* *Transactions of the Manchester Geological Society*, vol. xviii. pp. 373–379.

REFRACTORY MATERIALS.

A Deposit of Fire-Sand in Clinton County, New York.—According to Mr. A. F. Brainerd,* a large deposit of pure white sand occurs in Clinton County, near Mooer's Forks, about two miles from the railway station. The bed covers an area of 10 acres, with an average depth of 10 feet. It is mined by an open cut, no stripping being required. The sand has been employed in large quantities to cover the base of a 10-ton open-hearth furnace at the St. Albans Works.

An analysis of the sand gave the following results:—

Silica.	Fe_2O_3.	Al_2O_3.	MgO.	Loss by Ignition.	Total.
98·88	0·14	0·59	0·05	0·26	99·92

These results show that the sand compares favourably with others of recognised good quality.

Fireclay in Pennsylvania.—At Saltsburg, Pennsylvania, a seam of fireclay, 8 feet in thickness, has recently been struck. It is stated † that the largest seam worked in the United States is one at Bolivar, Pennsylvania, which is about 20 feet thick. Several seams 6 feet and upwards in thickness are being worked near Uniontown.

The Manufacture of Firebrick.—Mr. R. A. Cook ‡ describes the mining of fireclay and the manufacture of firebrick at one of the largest establishments in America, at Mount Savage, Maryland, in the north-western portion of the Cumberland coalfield, where the brick-works have been in constant operation ever since 1837.

The clay-mine is situated on the south side of Savage Mountain, three miles from the ironworks. Levels are driven in the outcrop, and from these, galleries are driven at an angle up on the bed clear through the old workings. Chambers are driven from these galleries, connecting them as often as the nature of the ground permits. When these chambers are all driven through, that part of the mine is robbed of as many of the pillars between the chambers as it is safe to remove. For transportation of material the three-rail incline is adopted. It is of great length—a mile and a quarter—and the rise from the bottom to the top is 1240 feet. Six trucks run upon it at once; the three loaded ones coming down haul up the empty ones. Five men are all that are necessary to run 100 tons of fireclay a day, two tons being loaded on each truck.

---

* Paper read at the Pittsburg meeting of the American Institute of Mining Engineers, 1886.—*Transactions*, vol. xiv. pp. 757–760.

† *Iron Age*, vol. xxxvii. No. 2.

‡ Paper read at the Pittsburg meeting of the American Institute of Mining Engineers, 1886.—*Transactions*, vol. xiv. pp. 698–706.

The bed of clay is at the base of the coal measures, and varies from 8 to 20 feet in thickness. The clay is divided into two varieties, the hard grey and the soft plastic clay of much lighter colour. The manner in which these two clays are intermixed causes the difficulty in the mining work. The impurities in the clay are of the usual character, but fewer and smaller in amount. An average of several analyses of the clay gives the following figures:—

Silica.	Alumina.	Impurities.	Water.	Total.
55·75	33·23	2·06	10·37	101·41

The calcining kilns are built of brick, with a boiler-iron shell. They are 15 feet high and 8 feet in diameter, with fire-holes a few feet from the base. The top is dome-shaped, with a chimney from the centre having a damper on top. The clay is charged in through a hole near the top, and is drawn out at the bottom of the kiln on iron plates, through two drawing doors; 20 tons being the daily output of one kiln. The proportion of calcined clay used varies with the size of the brick and the purpose for which it is intended. From the crushing-pan, which consists of two heavy rollers on a revolving grate, the clay goes by an elevator, through the screens, into a hopper above the tempering-pan. This is like that used in crushing, but has a solid iron base. The clay is carried to the tables by an endless belt, and the bricks moulded by hand. They are dried on a brick floor heated by flues, and when dry enough are pressed in hand-presses. They are then ready for the kilns, two varieties of which are in use. One is the regular rectangular down-draught kiln. The other is a gas kiln, resembling the Hoffman kiln in that some solid fuel is used, and the heat from the burning bricks dries the brick gradually. It is, however, not a continuous kiln; it is rectangular instead of elliptical, and uses gas for its principal fuel. The kiln is 200 feet long, and holds 300,000 bricks. It takes 30 days to burn it from end to end. The gas-producer is on a truck, which runs on a track the full length of the kiln. The combined production of the works amounts to the equivalent of 20,000 nine-inch bricks a day.

Analysis of Beauxite.—According to J. Lang,* beauxite from Langsdorf (Upper Hesse) gave on analysis the following results:—

	Brownish Red.	Light Red.
Silica	5·14	10·27
Alumina	50·85	49·02
Ferric oxide	14·36	12·90
Ferrous oxide . . .	0·35	...
Lime	0·41	0·62
Magnesia	0·11	trace
Potash	0·09	0·11
Soda	0·17	0·20
Water (on ignition) . .	27·03	25·88
Water (at 100°) . . .	1·35	0·93
Carbonic anhydride . .	trace	0·26
Phosphoric anhydride . .	0·48	0·38
Totals . .	100·34	100·57

---

* *Berichte der deutschen chemischen Gesellschaft*, vol. xvii. pp. 2892–2894.

PRODUCTION OF PIG IRON.

CONTENTS.

	PAGE		PAGE
I. Blast-Furnace Practice . .	294	IV. Blast-Furnace Slags . . .	310
II. Hot-Blast Stoves . . .	307	V. Foundry Practice . . .	319
III. Chemical Composition of Pig Iron	308		

I.—*BLAST FURNACE PRACTICE.*

The Charcoal Blast Furnaces at Anniston, Alabama.—The Woodstock Iron Company owns large deposits of iron ore at Anniston, Alabama. The ore is roasted in heaps, and then yields in the blast furnace 50 per cent. of iron. It is smelted with charcoal, which is made in pits, yellow pine being the wood generally employed. Blast of a temperature of from 500° to 550° F. is used, the average consumption of charcoal per ton of pig iron produced being 108 bushels. The two blast furnaces have the following dimensions:—

	No. 1.	No. 2.
	Feet.	Feet.
Total height	50	50
Diameter at the throat. .	8	7
Diameter at the bosh . .	11	12
Diameter at the hearth .	5	5½
Height of bosh . . .	8	8
Height of hearth . . .	6 ft. 10 in.	6 ft. 10 in.

The first of these two furnaces is stated to work better than the other.*

The Shelby Blast Furnaces, Alabama.—The first blast furnace erected in Alabama is stated to have been built about 1830, near the site of the present Shelby Ironworks. It had a capacity of 2 tons per day. The Shelby Ironworks now possess two blast furnaces, the dimensions of which are as follows:—

---

* *Iron Age*, vol. xxxvii. No. 7.

	No. 1.	No. 2.
	Feet.	Feet.
Total height	56	60
Height of bosh	20	23
Diameter at bosh	12	14
Height of hearth	3	4
Diameter of hearth	6	7

Each furnace has seven 3-inch tuyeres. No. 2 furnace has a tank water-jacket up to the mantle, and No. 1 a coal-jacket up to the top of the hearth, 3 feet.

Charcoal is employed as fuel, and the consumption ranges from 100 to 125 bushels to the ton of pig iron; 2 tons of roasted ore make 1 ton of pig. The iron is graded 1, 2, 3, 4, 5, 6, and 7. Nos. 1 and 2 do not chill; No. 3 chills to 0·25 inch; No. 4, to 0·5 inch; No. 5, to 1 inch; No. 6 is mottled; No. 7 white. The ore is obtained in the immediate neighbourhood of the furnaces, and enormous quantities of it are present. The screening is effected by machinery, cams giving an up-and-down motion to the screen, and an eccentric the side movement.

The limestone used is crushed by a Gates crusher, the capacity of which is 1 ton in five minutes. About 18 per cent. of lime is used per ton of iron made.*

A Chilled Blast-Furnace Hearth.—Mr. J. Gayley † calls attention to the following case:—On December 31, 1885, all the furnaces at the Edgar Thomson Works had to be banked very suddenly; and it was not until January 20, 1886, that matters were so arranged as to allow of starting up. When furnace E was opened everything was found in a satisfactory condition. The furnace was started, and made good progress until a heavy slip occurred on one side of the furnace, and five minutes after two more followed in quick succession on the other side and the back. Cinders ran freely out of all the plug-holes and joints of pipe connections, closing up five of the tuyeres. When the engine was stopped the belly-pipes were taken down with difficulty, as the upper half was filled with iron that had partly solidified.

---

* *Iron Age*, vol. xxxvii. No. 13.

† *Transactions of the American Institute of Mining Engineers*, vol. xiv. pp. 779–784.

Only two of the tuyeres could be taken out, the others being too firmly embedded in iron.

Arrangements were then made to get the blowpipes at work. Two were fitted up and started by noon on January 22; one working in the cinder-notch, the other in No. 6 tuyere to the left. In a short time they commenced to melt, and as the cavity increased in size the progress was more rapid. For a distance of 2 feet towards the centre of the hearth the material was quite hard, and consisted mainly of iron. Beyond that it became softer, and showed more cinder. In six hours after starting, a cavity 6 feet long, 5 feet wide, and 4 feet high was melted out. The crust was then penetrated, and a quantity of good hot coke fell through. A tuyere was put in, the cinder notch closed, and the furnace started. The tapping-hole was opened in the same way, it being found that when the blowpipe had melted in a certain distance, and the cavity was well heated up, a tapping-bar could be driven through without much trouble. In the space of six days after the accident all the tuyeres were at work, and the furnace gave no further trouble.

The most interesting feature presented by the obstruction was the presence of such a large quantity of iron. In the material melted from the cinder-notch the proportion varied from 60 to 80 per cent. At all the tuyeres which were opened by the blowpipe fully 80 per cent. of iron was found. The proportion of cinder never exceeded 40 per cent., and it was generally less. The probable explanation for this condition of the hearth is, that the several slips brought down a large amount of reduced ore in a fine state of division, and this, absorbing all the heat of the hearth in melting, produced the sudden chilling.

The North Chicago Blast Furnaces.—The following is the record of six months' work at three North Chicago blast furnaces.* The figures under coke show the average monthly consumption per ton of iron produced :—

	No. 5.		No. 6.		No. 7.	
	Pig Iron.	Coke.	Pig Iron.	Coke.	Pig Iron.	Coke.
	Tons.	Lbs.	Tons.	Lbs.	Tons.	Lbs.
July	5,559	2,127	5,532	2,105	6,075	2,012
August	5,467	1,967	5,510	1,994	5,978	1,875
September	5,735	1,981	5,883	1,968	6,488	1,897
October	5,478	1,954	5,827	1,948	5,989	1,941
November	5,796	1,954	6,126	1,966	6,242	1,877
December	5,752	1,912	5,987	1,911	5,926	1,892
Totals . .	33,787	1,980	34,865	1,976	36,698	1,912

---

* *Engineering and Mining Journal*, vol. xli. p. 33.

Mr. F. W. Gordon[*] thinks that by the recent work of these furnaces the following debatable propositions are, at least, more nearly settled: (1.) Strict economy in fuel consumption can be effected, while the product is very great. (2.) In accompanying the great output by lowering the heat units employed to a unit of work, the temperatures throughout the furnace are lowered, except perhaps in the immediate vicinity of the tuyeres, and greater durability of the walls is thus secured. (3.) By proper construction and practice, the region of economic reduction has been so far increased that the gases pass away at an exceedingly low temperature, while they contain a maximum percentage of carbonic anhydride, as compared with any mineral fuel practice, though they flow with rapidity. (4.) The reduction of fuel consumption having been accompanied by increased output, while engine speed, pressure, and steam consumption have been reduced, the cost of plant per unit of production does not represent so great an outlay, while the parts are not driven so fast. (5.) As out of 69,217 heat units developed 11,073 come in with the blast, much of the economy must be credited to superheated blast, independently of the changed condition of the descending material tending towards further economy in part resulting from this heat.

The Work of the Tecumseh Charcoal Furnace.—General Millard Warner, in a letter to the United States Association of Charcoal Ironworkers, gives a report of the work of the Tecumseh Furnace, Alabama. The furnace made, in $29\frac{3}{4}$ days, in September last, 785 tons of No. 1 iron, $282\frac{1}{2}$ tons of No. 2 iron, and 70 tons of No. 3 iron; total, $1137\frac{1}{2}$ tons, or $38\frac{33}{100}$ tons per day. Bushels of charcoal per ton, 106 (20 lbs. to the bushel). The yield of the ore was $52\frac{3}{10}$ per cent.; the consumption of limestone per ton of iron, 884 lbs.; the furnace was worked with one-fifth washed ore raw and part of roasted ore not well burnt; the weather was wet; men employed, thirty; make of iron per man per day's work, $1\frac{26}{100}$ tons. They took limestone and coal from trucks, and ore from the stockhouse. The labour includes one engineer and two helpers, one smith and helper, two founders, and includes crushing ore and limestone, taking out and weighing iron, stacking iron on furnace-yard, removing cinder, and all furnace labour.

Plant for Iron Smelting by Water-Gas.—Mr. M. Moxham[†] describes the plant recently erected at Trimsarran. This consists of one blast furnace, 43 feet high and 7 feet in diameter, resting on a cast-iron basement plate, supported on columns 12 feet in height from the ground. The upper part is constructed in the usual manner with firebrick lining and wrought iron cylindrical shell. The crucible and hearth is constructed according to Healy and Thwaite's patent. The crucible is 7 feet in diameter at the top, 8 feet deep, and 3 feet diameter at bottom, below which the hearth extends with perpendicular sides for a further depth of 3 feet; the tuyeres being placed 2 feet above the bottom of the hearth. The crucible and hearth have an internal lining of 4½ inches of magnesite bricks, backed with 6 inches of dolomite, behind which is a 3-inch lining of powdered bauxite, encased with 9 inches of firebrick and wrought iron outer shell. There are two tuyeres, placed opposite to each other, blown with combined jets of hot-air blast and water-gas, which are thoroughly mixed before entering the furnace. The pressure of air-blast and of gas is 5 lbs. The top of the furnace is closed with the usual bell and cup, and an arrangement is made by which the charge is allowed to remain in a chamber above the bell, to drive off moisture, before descending into the furnace. The furnace gases are taken off in the usual manner, and used for heating the stoves. At the back of the furnace are placed four brickwork hot-air stoves, each 43 feet high, and 6½ feet internal diameter, for supplying hot-blast at a temperature of 1500° Fahr. Conduits, with suitable valves, lead the air direct to the tuyeres and the gas producers.

---

[*] *Transactions of the American Institute of Mining Engineers*, vol. xiv. pp. 362–371.

[†] *Proceedings of the South Wales Institute of Engineers*, vol. xiv. pp. 295–302.

In front of the furnace are placed the gas producers in groups of four to the right hand and four to the left. Each producer consists of a generator and a recuperator. The generator is a vertical firebrick chamber, 13 feet high and 4 feet in diameter, encased with a wrought iron shell. It is provided with a connection to the water-gas main near the bottom, and, some 2 feet lower, a connection to the hot-blast main. The recuperator is a vertical firebrick chamber, 20 feet high and 4 feet in diameter, encased in a wrought iron shell, standing close to the generator, and connected with it by a gas main passing from the top of the generator to the top of the recuperator. The recuperator chamber is filled with firebrick, and is provided with a gas outlet main, and a steam inlet pipe at the bottom. The gas outlet leads to the chimney stack, and the steam-pipe to a receiver 20 feet long by 7 feet diameter, loaded at 5 lbs. pressure, and supplied from a boiler of ample capacity. The tops of the generators and recuperators are placed on the same level, so that the bottom of the generators stand on columns 7 feet above the ground. At a point in the hot-blast main convenient to each of the groups of generators, provision is made by which cold air can be injected by a Körting blower, so as to cool down the blast to the temperature most suitable for the fuel used in the generator.

The heated gases flowing off at the top of the generator pass into the combustion chamber at the top of the regenerator, where a proper supply of fresh air is admitted, and the burning gases, in passing down through the recuperator, soon raise the brickwork to an intense white heat. The hot-blast inlet valve to the generator and the outlet gas valve from the recuperator are then closed, and the inlet steam valve to the recuperator and the outlet gas valve from the generator opened, when the steam pressure immediately reverses the current, and the steam, rushing up through the recuperator, becomes highly superheated, and in passing down through the incandescent fuel of the generator becomes thoroughly decomposed, the oxygen being absorbed by the carbon of the fuel, and ultimately passing off as carbonic oxide, whilst the hydrogen is set free. It is found in practice that the water-gas thus produced consists of—

Carbonic oxide	40·00	to	45·00
Hydrogen	50·00	to	53·00
Nitrogen (from air leakages)	3·50	to	0·50
Carbonic anhydride	6·50	to	1·50
Total	100·00		100·00

The gas thus produced is then passed along the water-gas mains to the tuyeres, where it is ultimately mixed with the ingoing hot-blast immediately before entering the furnace; the combined jet having the reducing power and intensity of the oxyhydrogen blowpipe.

In working the gas producers, one pair of each group is always discharging water-gas into the mains, whilst two pairs of each group are heating up, and the fourth pair is held in reserve.

The Manufacture of Spiegeleisen from Franklinite Residuum.—According to Mr. G. C. Stone,* the New Jersey Zinc Company was the first to make spiegeleisen from franklinite residuum. Its first furnace was built in 1855. It was 19 feet by 7 feet, with open front and open top, a rectangular hearth, and three 3-inch tuyeres. The plant at present consists of two furnaces—A, 35 feet 7 inches by

* *Engineering and Mining Journal*, vol. xli. pp. 208–209, 229–230 247

8 feet; and B, 34 feet 4 inches by 8 feet; the blast for each furnace being heated by a 21-pipe Cowper stove.

The ores used are essentially a mixture of willemite, franklinite, zincite, and calcite, from Sterling and Franklin, New Jersey. The following analyses show the composition of the ores:—

	Selected Buckwheat (Franklin).			Lean Buck-wheat (Franklin).		Sterling Hill Mine.			Front Vein (Frank-lin).
	No. 1.	No. 2.	No. 3.	No. 1.	No. 2.	No. 1.	No. 2.	No. 3.	
Silica	10·21	9·91	11·08	10·28	10·33	4·86	4·43	5·15	9·78
Ferric oxide . .	31·41	31·63	27·54	30·46	30·36	30·33	30·13	27·62	27·20
Manganous oxide .	15·84	16·46	17·63	15·66	15·95	12·30	12·21	13·09	17·81
Zinc oxide . . .	32·83	34·07	35·88	27·15	26·34	29·42	27·12	23·38	22·94
Lime	5·09	4·08	2·01	8·45	7·15	12·65	12·63	14·37	11·46
Magnesia . . .	...	0·21	0·77	0·91	1·09	...	1·69	1·98	0·74
Alumina. . . .	0·21	0·80	0·24	0·09	1·16	0·67	...	0·64	0·67
Iron	21·98	22·14	19·28	21·32	21·25	21·23	21·09	19·33	19·04
Manganese . . .	12·27	12.75	13·65	12·12	12·35	9·53	9·46	11·13	13·79
Zinc	26·34	27·34	28·78	21·79	21·14	23·61	21·76	18·76	18·41

The ores are mixed in various proportions, limestone being added when necessary, and treated in the oxide furnaces where the greater part of the zinc is volatilised, to be sold as oxide. The clinker, as it comes from the oxide furnaces, is in flat cakes or in small fragments. It is screened before going to the blast furnaces, the very fine portion being rejected. The coal used is Lehigh "broken," usually rather higher in ash than it should be.

The first furnaces were small and worked very irregularly. The new closed-topped furnaces are larger than the old, and work rather more economically, using less coal and less labour to the ton of iron, though both are still very high when compared with large iron furnaces. It is only necessary to stop once a week for from one to two hours, to clean out. Undoubtedly larger furnaces would be more economical if they could be used, but the danger from zinc is too great. With the furnaces 30 feet high, a ring of oxide 4 feet deep forms on the throat, and with larger furnaces it would be deeper and too far down to allow of its removal.

The new "B" furnace was blown in on October 8, 1883. It is 30 feet high to the top of the stock-line, 6 feet in diameter at the throat, 8 feet at the bosh, 5 feet at the tuyeres, and 4½ feet at the bottom of the hearth. It has 5 tuyeres 2¾ inches, and one, over the tap-hole, 2 inches in diameter. It has water-cooled cast iron plates at the tuyeres, tap-hole, and cinder-notch, and a wrought iron jacket, cooled with spray pipes, from above the tuyeres to the mantle. Below the tuyeres there is a wrought iron jacket about 3 inches from the brickwork, with the intermediate space filled with chips of firebrick. The furnace now (January 1886) works a charge of 900 lbs. coal, 1200 lbs. clinker, 275 lbs. limestone, and makes 9 tons a day, averaging 20 per cent. of manganese.

The new "A" furnace is by far the best furnace ever erected at the works. It is 31 feet high to the stock-line, 6 feet 6 inches diameter at the throat, 8 feet at the bosh, and 5 feet 3 inches at the tuyeres. The bell is 3 feet 4 inches in diameter. There are five 3-inch and one 2¼-inch tuyeres. The walls are 21 inches thick up to the tuyeres, 16 inches at the bosh, 24 inches for the first 10 feet above the mantle, and 16 inches at the throat. The increased thickness of the walls appears to be one of the principal reasons for the better working of the furnace. From 1 foot below the hearth to 14 inches below the tuyeres, and at the tuyeres and cinder notch, the furnace has cast iron water jackets. From 14 inches above the tuyeres to the mantle there is a wrought iron bosh jacket with sprinkling pipes. The present charge of the furnace is 900 lbs. coal, 1275 lbs. clinker, and 300 lbs. limestone; the make being over 10¾ tons a day.

The zinc in the ore is the great trouble. It necessitates a peculiar construction of the furnace tops, and an elaborate system of gas-flues and condensers, or dust-catchers, and entails a great loss of time in cleaning them. The oxide is used to make zinc, producing a metal of exceptional purity.

The usual cinder from the furnaces is very nearly a mono-silicate. Good cinder usually has a flat or convex surface, is of a light green or brown colour, is very fluid when hot, and brittle when cold. Poor cinder has a flat or concave surface, is dark green or black, and is usually tough when cold, and frequently has a vitreous fracture. Analyses of the cinder gave the following results:—

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.
Silica	34·66	33·68	32·60	37·48	38·78	36·64	36·80	33·58
Ferrous oxide . .	2·43	0·68	2·85	1·68	2·57	1·78	1·54	1·20
Alumina . . .	8·87	13·00	13·06	9·12	13·30	12·08	9·08	9·88
Manganous oxide .	15·44	15·89	13·07	12·99	10·45	9·54	9·62	7·62
Lime	29·66	30·38	30·58	23·88	24·30	28·40	28·08	35·47
Magnesia . . .	8·46	6·27	6·54	13·74	11·78	11·12	13·92	11·19
Totals . .	99·52	99·90	98·70	98·89	101·18	99·56	99·04	98·94
Manganese . .	11·96	12·30	10·12	10·06	8·09	7·39	7·45	5·90

Nos. I. and II. are from the old open-topped furnaces; III., IV., V., VI., VII., are from the new furnaces; VIII. is Passaic cinder.

The spiegeleisen is divided into 10 grades—"scrap" being all containing less than 10 per cent. of manganese. The other grades are: 10 to 12 per cent., 13 to 16 per cent., 17 to 19 per cent., and 20 per cent. At first the iron made was very low in manganese, but has gradually improved, until most of it contains over 20 per cent.

In conclusion the author describes the furnaces belonging to the Lehigh Company and the Passaic Company. The Lehigh Company built its furnace in 1881. The residuum employed frequently contains 32 per cent. of silica. The furnace is 32 feet 9 inches high, 5 feet 4 inches diameter at the throat, 8 feet at the bosh, and 4 feet at the tuyeres, with closed top and front. It has 4 tuyeres 3 inches in diameter. The usual pressure of blast is 4½ lbs., and the temperature 700° F. The average length of blast is 16 months. The furnace is stopped twice a week, for an hour each time, for cleaning. The gas passes through 6 condensers with 5 pipes to each. These condensers catch 405 lbs. of oxide per ton of iron made. Per ton of iron made there are used: boiler coal 1·08 tons, furnace coal 2·79 tons, coke 0·72 tons, residuum 3·59 tons, limestone 1·65 tons. The usual charge is, fuel 700 lbs., residuum 700 lbs., limestone 320 lbs. The spiegeleisen contains 14 per cent. of manganese; and the cinder contains 33·33 per cent. of silica, and 3·89 per cent. of manganese.

The Passaic Company built its furnace in 1883. It is 34 feet 9 inches high, 10 feet diameter at the bosh, and 5 feet 8 inches at the tuyeres. The top is closed by a bell and hopper, and the furnace is water-jacketed. The average pressure of blast is 5½ lbs., and the temperature 881° F. For the year 1885 there were used to the ton of iron, boiler coal 0·57 ton, furnace coal 2·29 tons, residuum 2·89 tons, limestone 0·63 ton, and scrap 25 lbs. The average make per day was 11 tons 1792 lbs., with 22·76 per cent. of manganese. The furnace has a double set of condensers, one set only being used at a time. There are 8 condensers in each set. Each is 34 feet 8 inches high, with 9 pipes 1 foot in diameter and 24 feet long. At first, the Passaic Company used wet scrubbers for the gas, but finally abandoned them. They are now used without water.

The Distribution of the Manganese in the Spiegeleisen Furnace.—Mr. J. A. Jardine * gives an interesting account of the special practice at the Bethlehem Works, Pennsylvania. The furnace is small, having a height of 32 feet 6½ inches to the charging floor, a diameter of 8 feet at the bosh, and 4 feet 9 inches at the hearth. There are four tuyeres arranged at equal distances round the hearth. A shell of one quarter-inch boiler iron extends round the furnace to within 5 feet 9 inches of the top, and a water coil surrounds the furnace at the bosh. The pressure of the blast averages 4 lbs. above atmospheric pressure, and the temperature ranges from 750° to 850° F. The spiegeleisen is made from the residuum obtained in the treatment of a mixed ore from Franklin, New Jersey. An analysis of this residuum from the zinc furnaces gave the the following percentages:—

---

* *Engineering and Mining Journal*, vol. xli. p. 151.

Iron.	Manganese.	Silica.
21·50	8·71	35·12

A charge for the furnace consisted of:—

Residuum.	Anthracite.	Coke.	Flux (CaO).
800 lbs.	525 lbs.	175 lbs.	260 lbs.

The number of charges in a 12-hour day shift varies from 24 to 32. The night turn makes 4 to 7 charges more. The furnace is tapped every 6 hours for spiegeleisen and every hour for slag. The flue-dust is mainly zinc oxide with some metallic zinc, and is termed *blue powder*.

In order to learn the distribution of the manganese, samples of the residuum, slag, spiegeleisen, and blue powder were collected during a period of 48 hours, while the furnace was working regularly, and an analysis made of each. In all cases, great care was taken to obtain a fair sample.

The weights of the materials in the charge and of those in the product were:—

	Tons.
The make of spiegeleisen during the 48 hours . . .	11·82
,, blue powder during the 48 hours . . .	1·49
The weight of residuum charged	46·00
,, fuel	40·25
,, lime	14·95

Hence, per ton (2000 lbs.) of spiegeleisen, the charge was:—

	Tons.
Residuum	3·89
Fuel	3·40
Lime	1·26

0·126 ton of blue powder being produced. The weight of slag taken from the furnace was determined by calculation from the results of the analyses; all the silica of the charge being assumed, with considerable accuracy, to enter the slag, less that which enters into the composition of the spiegeleisen as silicon and in the blue powder as a silicate. In this way the weight of silica entering the slag produced was found to be 1·438 ton per ton of spiegeleisen. The slag contains 35·61 per cent. of silica. The weight of slag per ton of spiegeleisen is consequently 4·04 tons.

The percentages of manganese are as follows:—

	Per Cent.
Residuum	8·71
Spiegeleisen	14·57
Blue powder	1·95
Slag	4·41

The weights of manganese charged per ton of spiegeleisen are:—

	Tons.
Residuum	0·3388
Spiegeleisen	0·1457
Blue powder	0·0024
Slag	0·1782

The amount of manganese charged (0·3388 ton) per ton of spiegeleisen is distributed as follows:—

	Per Cent.
Spiegeleisen	43·00
Slag	52·58
Blue powder	00·72
Total	96·30

This result leaves 3·7 per cent. unaccounted for; but from the appearance of the escaping gases, it is fair to assume that some manganese is lost by oxidation.

Ferro-Manganese Manufacture.—In a note appended to a translation of Pourcel's paper on this subject,* Mr. G. C. Stone † states that, in making high-grade spiegeleisen (20 to 25 per cent.) from franklinite residuum, he has found the most suitable cinder is one in which the oxygen in all the bases is equal to the oxygen in the silica. If more or less limestone is added than is necessary to produce this result, the cinder will contain an excessive quantity of manganese. From the material treated at the New Jersey Zinc and Iron Company's works at Newark, more than 50 per cent. cannot be extracted, because, if the attempt is made, so large a proportion of coal has to be used that it does not pay, and the high heat makes the spiegeleisen too silicious to be marketable. A high temperature of the blast may not be necessary, but is very advantageous, as adding heat by the blast is less likely to make the spiegeleisen high in silicon than adding it by using a larger proportion of fuel.

---

* See *Journal of the Iron and Steel Institute*, 1885, p. 251.

† *Engineering and Mining Journal*, vol. xl. p. 353.

The graphite hearth, advocated by Pourcel, is necessary at Terrenoire, the cinder there containing too litttle lime, and therefore too much manganese, and consequently being of a kind that cuts the ordinary acid hearth. A few years ago, when spiegeleisen with 12 to 16 per cent. of manganese was being made at the New Jersey works, the furnaces were continually breaking out into the hearth. Now, while 20 to 25 per cent. spiegeleisen is being made from the same material, the hearth is apt to fill up with graphite.

The best arrangement for preventing the inconvenience of zinc fume is at the furnace of the Passaic Zinc Company, where there is a double set of condensers, the gas passing through one set while the other is cleaned. By opening and shutting two valves, the gas is transferred to the clean set without stopping the furnace. Wet scrubbers have been tried at Bethlehem and at the Passaic works, but have not proved a success.

The Cost of Production of Pig Iron in the United States.— In reply to a circular issued by the Secretary of the Treasury, the Eastern Pig Iron Association, United States, states* that at the present time no blast furnace can afford to be in blast unless the ore costs less than 8 cents. per unit, *i.e.*, 8 dollars for the quantity of ore required to produce a ton of pig iron. Foreign ores, imported for the manufacture of Bessemer steel, come chiefly from Spain, Algiers, and the Island of Elba, and they have recently been introduced from Cuba. Such ores, averaging 50 per cent. of metallic iron, can be laid down in the Atlantic ports for about 4 dollars per ton, including the duty of 75 cents per ton.

The limestone used per ton of pig iron costs from 50 cents to 1 dollar, 80 to 90 per cent. of this cost being for labour, 5 per cent. for royalty, and the balance for transport.

The fuel costs, in the case of charcoal, about 7 cents per bushel, from 90 to 150 bushels being required per ton of pig iron produced. Coal and coke costs from 5 dollars to 6·5 dollars per ton of pig iron. Of this cost 30 to 60 cents are for royalty, the balance being for labour and transport. Two-thirds of the cost of transport is due to labour. The cost of furnace labour, including handling materials and product, with superintendence, averages, at a well-managed furnace, 2 to 2·5 dollars per ton of pig iron. Taking 2 dollars as the standard, the items are as follows:—

---

* *Iron Age*, vol. xxxvii., No. 9.

	Dollars.
Superintendence, including clerical labour	0·30
Cinder-men (removing slag)	0·30
Fillers (putting materials into furnace)	0·70
Iron-men (preparing beds and handling iron)	0·20
General men (blacksmiths, enginemen, labourers, &c.)	0·50
Total	2·00

The rates of wages range from 11 cents per hour for unskilled labour to 1·75 dollar and 2·5 dollars per day for skilled mechanics.

Incidental expenses, including small daily repairs, forage for horses, oil, &c., average about 0·75 dollar per ton of iron.

Larger repairs, relining of furnaces, &c., cost on an average 0·5 dollar per ton, and the Association gives the following statements of the actual cost of making pig iron at four works in different parts of the country east of the Alleghany Mountains, which may be taken as typical establishments in the districts where they are situated.

The statement relates to the years 1882, 1883, and 1884:—

Tons of Iron Made.	Fuel.	Ore.	Lime-stone.	Wages and Salaries.	Inci-dentals.	Repairs.	Total Cost.
	Dollars.	Dollars.	Dollars.	Dollars.	Dollars.	Dollars.	Dollars.
I. 64 200	5·15	8·50	0·07	2·25	0·43	...	16·40
II. 96·000	5·47	9·58	0·42	1·82	0·72	0·69	18·70
III. 52·152	5·96	9·26	0·82	2·10	0·62	0·19	18·95
IV. 90·500	6·50	9·00	0·69	2·37	1·10	0·15	19·81

The cost of a furnace plant capable of producing from rich ores 100 tons of pig iron per day is stated to be as follows:—

	Dollars.
Furnace stack	30,000
Casting-house	10,000
Stock-house	10,000
Engine-house	10,000
Boiler-house	5,000
Hot-blast stoves	40,000
Machinery	80,000
Hot-blast pipes and cold-air pipes	10,000
Elevator	5,000
Total	200,000

This cost does not include cost of land, engines and trucks, houses for workmen, &c. Working on rich ores, the interest on this sum per ton of pig iron would be about 32⅞ cents, and with a daily output from poor ores of 70 tons, the interest would amount to 46·9 cents per ton of pig iron. Supposing the furnace to purchase all the materials used, and to carry unsold only six weeks' production, a working capital of at least 75,000 dollars would be required. The interest on this per ton of pig iron, with a daily make of 100 tons, would be 12·33 cents, and with a daily make of 70 tons, 17·6 cents. Other elements of cost, such as taxes, insurance, and commissions on sales (about 1 per cent.), the cost of reaching the market, &c., average about 1 dollar per ton.

Referring to the cost of production in Europe, the Association draws attention to the full details on this subject contained in Sir Lowthian Bell's recent work, and they add that they are of opinion that the only certain method to secure an adequate, regular, and satisfactory supply of the raw materials used in the production of pig iron, is to maintain adequate protective duties upon such materials as are produced in the United States.

The Cost of Production of Pig Iron in Alabama.—The following is an estimate of the cost of production of a ton of pig iron in Alabama, United States:—

	Dollars.
2·5 tons of ore	2·58
1·0 ton of limestone	0·70
1·7 ton of coke	3·91
Labour and management	2·25
Incidental expenses and depreciation	1·00
Total	10·44

To this, however, must be added the taxes, interest on capital employed, &c.; and supposing the sum allowed above for depreciation in plant was too low, it is considered that the lowest cost of production would amount to 11·7 dollars.*

The Formation of Ozone in Blast-Furnaces.—E. Tscheuschner † notices the formation of ozone in blast-furnace practice. He is in doubt as to the cause of the formation of this substance, but has observed its presence in considerable quantities.

II.—*HOT-BLAST STOVES.*

Gordon's Cowper-Whitwell Stoves.—Mr. V. O. Strobel ‡ describes an improved type of three-pass regenerative hot-blast stove.

---

* *Iron Age*, vol. xxxvi. No. 21.

† *Chemiker Zeitung*, vol. x. p. 83.

‡ Paper read at the Chattanooga meeting of the American Institute of Mining Engineers. *Transactions*, vol. xiv. pp. 159–172.

The details of construction are shown by means of six illustrations. The advantages claimed for this stove are—its simplicity of construction, the costly underground chimney flues and draft-stack being avoided; the increased area of passes and valves, permitting 50 per cent. more gas to be passed through them; the capacity of heating a greater volume of gas to a higher temperature; finally, its low initial cost as compared with other firebrick stoves.

Two of these stoves are being erected[*] at the Jefferson Ironworks, Steubenville, Ohio. They are each 17 feet in diameter, and 65 feet high, the peculiarity of these stoves being that each carries its own chimney. The heating surface of the stove will be 21,700 square feet, with a capacity of flow for the heating gases of 138 cubic feet per second. They are intended to be used to heat the blast for a daily out-turn of 100 tons of pig iron with a consumption of about 1900 lbs. of coke to the ton of iron. The blast furnace, which is now being built, will be 60 feet high, and 14·5 feet wide at the bosh.

III.—*CHEMICAL COMPOSITION OF PIG IRON.*

Analyses of Austrian Pig Iron.—Dr. E. Prziwoznik[*] publishes the following:—

No.	C.	Si.	P.	S.	Mn.	Cu.	Co+Ni.
1	2·582	0·105	0·070	0·040	1·422	...	...
2	3·243	0·149	0·136	0·039	2·377	trace	...
3	3·563	0·075	0·535	0·028	2·470	0·030	...
4	3·186	0·568	0·098	0·059	2·465	trace	trace
5	3·486	0·056	0·060	0·022	1·365	trace	trace
6	3·182	0·144	0·058	0·034	1·749	trace	trace
7	3·127	0·285	0·063	0·016	1·694	trace	trace
8	3·980	0·168	0·073	0·021	2·180	trace	trace
9	3·393	1·640	0·143	0·016	4·430	trace	...
10	2·791	4·822	1·281	0·011	trace	0·015	0·016
11	2·819	2·831	0·124	0·025	3·786	0·005	trace
12	2·938	3·371	0·154	0·030	2·748	0·001	...
13	...	0·392	0·125	0·052	2·186	0·075	...
14	0·155	0·028	0·043	0·013	0·063	0·003	...
15	0·078	0·028	0·063	0·012	0·076	0·007	trace

White pig iron:—1. From Vordernberg, cold blast. 2. From Schwechat. 3. From Betlér. 4, 5, 6, 7, 8. From Eisenerz. Foundry pig iron:—9. From Schwechat. 10. From Rokycan. 11. From Eisenerz. 12. Grey pig iron from the Dernö Works, Hungary. 13. White pig iron from Dobschau. 14. Fined iron from Vordernberg cold blast pig iron. 15. Fined iron from Schwechat coke pig iron.

---

[*] *Iron Age*, vol. xxxvi. No. 18.

[†] *Berg- und Hüttenmännisches Jahrbuch der k. k. Bergakademien*, vol. xxxiv. p. 56.

Siegen Spiegeleisen.—The following analyses of Siegen spiegeleisen are by Dr. W. Thörner:*—

	I.	II.
	Per cent.	Per cent.
Iron	80·38	73·44
Manganese	14·13	20·04
Carbon	4·78	5·60
Silicon	0·32	0·32
Phosphorus	0·07	0·08
Sulphur	0·00	0·00
Copper	0·34	0·20
Cobalt } Nickel }	0·20	0·28
Totals	100·22	99·96

The Constitution of Pig Iron.—As showing how completely the usual ultimate chemical analysis of cast metal fails to explain the ordinary conceptions in regard to the relation between the chemical constitution and the physical properties, Messrs. C. B. Dudley and F. N. Pease,† give the analyses of two cast-iron wheels. Both wheels were of approximately the same weight, both were cast in the same kind of mould, and poured at approximately the same temperature. One of the wheels had been in service, the other had not. The good one, which had not been in service, required 150 blows with a 25-lb. hammer to break a piece out. The other required eight blows with the same hammer. The results of the analyses were as follows:—

	Total Carbon.	Graphite.	Combined Carbon.	Silicon.	Phosphorus.	Manganese.	Sulphur.
I.	3·84	3·30	0·54	0·69	0·43	0·13	0·12
II.	3·53	2·36	1·17	0·65	0·52	0·12	0·19

I. Good wheel. II. Poor wheel.

From a large number of experiments with these two wheels, and upon other metal, there seem to be indications of two things:—(1.) That the carbon in pig iron exists in three forms—as graphite, as carbide of iron, and possibly combined with the iron in the same way that it is combined with the iron in steel—a form which the authors term strength-carbon. (2.) There are indications that the carbide of iron before referred to is the principal cause of the great difference in strength between the good and poor wheel.

A study of the microscopic structure of the iron of these wheels was made by Mr. F. L. Garrison. On examining the iron of the good wheel under the microscope, the plates and lines of graphite are very marked, and appear as an irregular mass of small black lines. The surrounding mass of metal presents a compact, granular, non-crystalline structure, frequently exhibiting cavities due to occluded gas. Very little of the graphite occurs in isolated irregular patches, as will be seen to be almost always the case in the poorer grades of cast-iron.

---

* *Stahl und Eisen*, vol. vi. p. 103.

† Paper read at the Pittsburg meeting of the American Institute of Mining Engineers, February 1886. *Transactions*, vol. xiv. pp. 795–801.

In the poor wheel iron, although the mass of the metal itself appears to be the same as that of the good wheel, the well-developed and prominent graphite plates are absent, and are replaced by the graphite in irregular and somewhat isolated patches of comparatively large size, and without any regular grouping. This peculiarity seems characteristic of the poorer grades of cast-iron. In nearly all cases metal showing it is untrustworthy, lacking the toughness and durability of the better grades.

These facts indicate that the development and distribution, in well-defined lines or plates, of the graphitic carbon is at least as important a factor of quality, up to a certain limit, as its total amount.

IV.—*BLAST-FURNACE SLAGS.*

The Heat required for the Fusion of Blast-Furnace Slags.—After referring to the investigations of Sefström, Berthier, Plattner, Percy & Smith, Bischof, Rinman, Gruner, and Bell, Professor R. Åkerman * points out that the results obtained by these investigators are not comparable, owing to the methods of examination adopted, and that he was therefore led to commence the experiments the results of which he now publishes.

For the determination of the latent heat of fusion the author employed the Andrée calorimeter,† and to avoid errors due to the temperature not being that of the actual fusion point, the crucible was only partially emptied into the calorimeter, about one-half of the solidified slag being allowed to remain in the crucible. In the experiments there were employed finely powdered mixtures of the following minerals:—

1. Quartz from Mejdasen in Dalarne, containing—

SiO_2.	Al_2O_3.	CaO.	MgO+MnO.	FeO.	Total.
98·52	0·12	0·43	traces	0·48	99·55

---

* "*Om värmebehofven för olika masugnsslaggers smältning,*" Stockholm, 1886, 77 pp.

† See *Journal of the Iron and Steel Institute*, 1885, p. 325.

2. Limestone from Strand in Dalarne, with—

$CaCO_3$.	MgO.	MnO.	FeO.	Al_2O_3.	SiO_2.	Total.
94·47	2·00	0·19	0·48	0·41	2·47	100·02

3. Talc, containing—

SiO_2.	Al_2O_3.	CaO.	MgO.	MnO.	FeO.	H_2O.	Total.
59·27	0·91	1·33	32·08	trace	1·00	4·95	99·54

4. Magnesia, containing—

Na_2O.	CaO.	MgO.	Al_2O_3.	SiO_2.	H_2O.	Total.
0·07	1·50	94·62	0·40	0·45	3·10	100·14

5. Kaolin, containing—

SiO_2.	Al_2O_3.	K_2O.	Na_2O.	CaO.	MgO.	FeO.	H_2O.	Total.
47·25	37·20	1·07	0·21	0·35	0·19	0·63	13·00	99·90

6. Alumina, containing—

SiO_2.	Al_2O_3.	Na_2O.	CaO.	MgO.	FeO.	H_2O.	Total.
1·20	63·50	0·37	0·06	0·02	trace	34·70	99·85

7. Manganese carbonate, containing—

Na_2O.	MgO.	MnO.	CO_2.	H_2O.	Total.
0·57	trace	58·60	36·80	3·30	99·27

Lime and Magnesia Silicate.—For the 1·5 and 2·0 silicate, the greatest fusibility is found with 9 CaO + 4 MgO, or with an oxygen and equivalent ratio of about 0·44. As the percentage of magnesia increases, the fusibility diminishes in almost the same ratio as that in which it had previously increased. Thus the bisilicate containing no magnesia fused with 473 calories, that with 9 CaO and 4 MgO with 375 calories, while in the case of the 1·5 silicate the numbers were respectively 431 and 411.

The 2·5 silicate possessed the greatest fusibility with 7 CaO + 2 MgO, or a ratio of 0·29; the silicate containing no magnesia fused with 446 calories, the one just mentioned with 362. More magnesia reduces the fusibility, but to a much less degree than in the cases of the 1·5 and 2·0 silicates.

The 3·0 silicate is within certain limits scarcely affected by the presence of magnesia. With regard to the relation between the oxygen of the base and that of the silica, the following were the results obtained:—

	Nature of Silicate.	Calories.		Nature of Silicate.	Calories.
(CaO) silicate . .	1·5	431	(2 CaO + MgO) silicate	1·0	483
	1·75	472		1·5	414
	2·00	472		1·75	423
	2·86	388		2·37	369
	4·0	424		3·18	409
(3 CaO + MgO) silicate	1·25	449	(CaO + MgO) silicate	1·0	513
	1·5	419		1·5	441
	1·75	435		1·75	467
	2·5	363		2·75	394
	3·0	395		3·5	456

Heat required for the Fusion of the 1·5, 2·0, 2·5, and 3·0 Silicates of Lime and Magnesia.

	Calculated Percentage Composition.						Equivalents of CaO and MgO in Percentages.		Of Slag Formed, there		Calories, per Unit of Weight of Slag in Calorimeter.	Character of the Slag				Character on Pouring.
												After Cooling in the Calorimeter.		After Cooling in the Crucible.		
	SiO_2.	Al_2O_3.	CaO.	MgO.	MnO.	Fe O.	MgO.	CaO.	Ran into Calorimeter.	Remained in Crucible.		Nature.*	Colour.	Nature.*	Colour.	
									Grammes	Grammes						
1·5 silicate, with varying ratios of MgO and CaO.	44·94	0·45	51·80	1·95	0·19	0·67	5·0	95·0	96·75	63·8	431	C.	grey	C.	grey	no threads
	45·24	0·48	49·84	3·56	0·18	0·70	9·1	90·9	72·56	65·8	430	C. + V.	,,	,,	,,	,,
	45·62	0·52	47·33	5·64	0·17	0·72	14·3	85·7	67·54	72·9	428·7	,,	,,	,,	,,	,,
	45·79	0·54	46·17	6·60	0·16	0·74	16·7	83·3	57·79	57·2	428	,,	,,	,,	,,	,,
	46·03	0·56	44·55	7·95	0·16	0·75	20·0	80·0	77·73	91·8	426	,,	,,	,,	,,	,,
	46·20	0·58	43·43	8·87	0·15	0·77	22·2	77·8	106·71	60·7	423	,,	,,	,,	,,	,,
	46·41	0·60	42·04	10·02	0·15	0·78	25·0	75·0	75·22	93·9	419	,,	,,	C. + V.	,,	,,
	46·68	0·62	40·24	11·51	0·14	0·80	28·6	71·4	71·55	53·5	413	,,	,,	,,	,,	,,
	46·85	0·64	39·13	12·43	0·14	0·81	30·8	69·2	78·86	77·0	411	,,	,,	,,	,,	,,
	47·10	0·70	37·80	13·50	0·10	0·80	33·3	66·7	110·24	119·9	414	,,	,,	C.	,,	,,
	47·57	0·71	34·36	16·38	0·12	0·86	40·0	60·0	71·13	86·8	424	,,	,,	,,	,,	,,
	48·40	0·80	29·00	20·80	0·10	0·90	50·0	50·0	96·19	94·3	441	C.	,,	,,	,,	,,
	49·51	0·90	21·46	27·05	0·07	1·01	63·8	36·2	58·71	44·3	489	,,	,,	,,	,,	,,
2·0 silicate, with varying ratios of MgO and CaO.	52·10	0·40	45·00	1·70	0·20	0·60	5·1	94·9	65·14	110·3	472	C.	grey	C.	grey	no threads
	52·79	0·46	41·02	4·89	0·15	0·69	14·3	85·7	49·92	87·4	450	C. V.	,,	C. V.	,,	,,
	53·20	0·50	38·70	6·80	0·10	0·70	19·6	80·4	112·44	128·8	437	C. + V.	,,	,,	,,	,,
	53·38	0·52	37·57	7·67	0·13	0·73	22·2	77·8	76·93	66·1	426	,,	,,	,,	,,	,,
	53·59	0·53	36·35	8·66	0·13	0·74	25·0	75·0	83·02	65·0	412	,,	,,	C. + V.	,,	some threads
	53·70	0·60	35·00	9·80	0·10	0·80	28·1	71·9	80·32	73·9	389	,,	,,	,,	,,	threads
	54·10	0·60	33·30	11·10	0·10	0·80	31·6	68·4	82·37	45·0	377	,,	,,	,,	,,	,,
	54·20	0·60	32·60	11·70	0·10	0·80	33·3	66·7	128·26	128·6	391	,,	,,	,,	,,	,,
	54·40	0·60	31·60	12·50	0·10	0·80	35·7	64·3	93·19	107·3	416	,,	,,	,,	,,	,,
	54·70	0·60	29·80	14·00	0·10	0·80	39·4	60·6	134·08	133·7	430	,,	,,	,,	,,	,,
	55·50	0·70	25·00	17·90	0·10	0·80	50·0	50·0	97·34	100·7	456	,,	,,	,,	,,	,,
	57·60	0·90	12·90	27·60	...	1·00	74·6	25·4	129·17	108·9	498	,,	,,	C.	,,	no threads
	58·50	0·90	7·90	31·70	...	1·00	84·7	15·3	112·06	96·2	540	,,	,,	,,	,,	,,

2·5 silicate, with varying ratios of MgO and CaO.	57·70	0·40	39·70	1·50	0·10	0·60	5·0	95·0	36·04	98·5	446	C.	grey	C.	grey	no threads
	57·90	0·40	38·17	2·73	0·10	0·70	9·1	90·9	51·81	86·4	412	C.+V.	,,	C.+V.	,,	some threads
	58·06	0·41	37·40	3·34	0·13	0·66	11·1	88·9	58·35	76·9	401	,,	,,	,,	,,	,, ,,
	58·16	0·41	36·87	3·77	0·13	0·66	12·5	87·5	60·92	83·8	391	,,	,,	,,	,,	,, ,,
	58·30	0·40	36·20	4·30	0·10	0·70	14·3	85·7	68·23	85·2	381	V.+C.	,,	,,	,,	threads
	58·50	0·40	35·30	5·00	0·10	0·70	16·7	83·3	76·36	77·5	369	,,	,,	,,	,,	,,
	58·70	0·50	33·90	6·10	0·10	0·70	20·0	80·0	100·00	100·0	363	,,	,,	V.+C.	,,	,,
	58·80	0·50	33·10	6·80	0·10	0·70	22·2	77·8	71·72	73·7	362	,,	,,	,,	,,	,,
	59·10	0·50	32·00	7·60	0·10	0·70	25·0	75·0	99·00	61·8	363	,,	,,	,,	,,	,,
	59·30	0·50	30·60	8·80	0·10	0·70	28·6	71·4	72·19	70·0	365	,,	,,	,,	,,	,,
	59·70	0·50	28·70	10·30	0·10	0·70	33·3	66·7	119·28	103·8	372	V.	,,	V.	,,	,,
	60·20	0·50	26·00	12·40	0·10	0·80	40·0	60·0	68·19	85·0	382	V.E.+C.	,,	C.+V.E.	,,	,,
	61·00	0·60	21·90	15·60	0·10	0·80	50·0	50·0	100·64	150·3	402	C.+V.E.	blue-grey	E.V.+C.	blue-grey	,,
3·0 silicate, with varying ratios of MgO and CaO.	62·00	0·40	35·60	1·30	0·10	0·60	4·7	95·3	86·02	86·8	396	C.+E.+V	blue-grey	C.+E.	blue-grey	threads
	62·12	0·36	34·99	1·79	0·12	0·62	6·7	93·3	95·66	53·9	387	E.+V.+C	,,	E.+C.	,,	,,
	62·19	0·36	34·64	2·07	0·12	0·62	7·7	92·3	75·72	77·1	386	E.+V.	,,	,,	,,	,,
	62·29	0·37	34·15	2·44	0·12	0·63	9·1	90·9	76·32	80·6	385	,,	,,	,,	,,	,,
	62·35	0·37	33·84	2·69	0·12	0·63	10·0	90·0	100·00	100·0	385	,,	,,	,,	,,	,,
	62·42	0·38	33·46	2·99	0·12	0·63	11·1	88·9	51·01	46·0	386	,,	,,	E.+E.C.	,,	,,
	62·52	0·38	32·97	3·37	0·12	0·64	12·5	87·5	88·88	61·7	387	,,	,,	E.+C.	,,	,,
	62·64	0·39	32·35	3·85	0·12	0·65	14·3	85·7	89·17	70·4	388	E.	,,	,,	,,	,,
	62·72	0·40	31·97	4·15	0·11	0·65	15·4	84·6	74·27	74·8	389	E+C.	,,	,,	,,	,,
	62·81	0·40	31·52	4·51	0·11	0·65	16·7	83·3	77·30	84·7	390	,,	,,	E.+E.C.	,,	,,
	62·91	0·41	30·99	4·92	0·11	0·66	18·2	81·8	80·37	83·9	391	E.+V.	,,	,,	,,	,,
	63·03	0·42	30·35	5·42	0·11	0·67	20·0	80·0	86·84	71·5	392	E.	,,	E.+C.	,,	,,
	63·19	0·43	29·56	6·04	0·10	0·68	22·2	77·8	78·80	86·6	394	,,	,,	E.+E.C.	,,	,,
	63·63	0·46	27·30	7·81	0·10	0·70	28·6	71·4	82·11	76·9	398	,,	,,	E+E.C+C	,,	,,
	64·00	0·50	25·60	9·10	0·10	0·70	33·3	66·7	94·05	84·2	402	E.+E.C.	,,	C.E.+E.	,,	,,
	64·45	0·52	23·17	11·04	0·08	0·74	40·0	60·0	74·13	89·6	407	E.+V.	,,	C.+E.	,,	,,
	65·10	0·60	19·50	13·90	0·10	0·80	50·0	50·0	109·33	141·0	417	E.	,,	E.	,,	,,
	65·38	0·61	16·17	16·52	0·06	0·81	58·8	41·2	36·67	128·6	429	E.	,,	E.+C.	,,	,,

---

* C. crystalline, V. vitreous, E. enamel.

Heat required for the Fusion of the 0·5, 0·7, 1·0, and 1·5 Silicates of Lime and Alumina in Varying Proportions.

	Calculated Percentage Composition.								Equivalents of Al_2O_3 and bases with 1 Atom Oxygen. Percentage.		Of the Slag formed, there		Calories per Unit of Weight of Slag in Calorimeter.	Character of the Slag				Character on Pouring.
											Ran into Calorimeter.	Remained in Crucible.		After Cooling in Calorimeter.		After Cooling in Crucible.		
	SiO_2.	Al_2O_3.	K_2O.	Na_2O.	CaO.	MgO.	MnO.	FeO.	Al_2O_3.	RO.	Grammes	Grammes		Nature.	Colour.	Nature	Colour.	
0·5 silicate of bases with 1 Atom Oxygen and Al_2O_3 in varying proportions	25·64	33·17	...	0·19	38·91	1·48	0·14	0·47	30·2	69·8	...	...	...	...	...	...	...	...
	25·97	35·66	...	0·21	36·22	1·37	0·13	0·44	33·3	66·7	83·71	23·0	406	V	Grey	V	Grey	Threads
	26·31	38·33	...	0·22	33·33	1·27	0·12	0·42	36·8	63·2	36·53	44·3	369	V	”	V	”	”
	26·61	40·61	...	0·23	30·87	1·17	0·11	0·40	40·0	60·0	100·0	100·0	384	V	”	V	”	”
	27·46	47·11	...	0·27	23·82	0·91	0·09	0·34	49·9	50·1	100·0	100·0	423	V+C	”	C+V	”	No threads
0·7 silicate, do. do. do.	30·27	16·50	...	0·09	50·46	1·91	0·18	0·59	14·3	85·7	51·75	41·15	447	O	Grey	O	Grey	No threads
	31·01	20·87	...	0·12	45·56	1·73	0·16	0·55	18·9	81·1	66·36	32·8	412	C.V+V	”	C.V	”	”
	31·61	24·48	...	0·14	41·53	1·57	0·15	0·52	23·1	76·9	45·52	54·9	380	V	”	V	”	Threads
	32·12	27·51	...	0·16	38·14	1·44	0·14	0·49	26·8	73·2	41·88	40·3	357	V	”	V	”	”
	32·35	28·84	...	0·17	36·64	1·39	0·13	0·48	28·6	71·4	44·62	51·9	355	V	”	V	”	”
	32·55	30·09	...	0·17	35·25	1·34	0·13	0·47	30·2	69·8	42·90	40·6	359	V	”	V	”	”
	32·93	32·30	...	0·19	32·78	1·24	0·12	0·44	33·3	66·7	76·22	49·2	370	V	”	V	”	”
	33·67	36·70	...	0·21	27·86	1·06	0·10	0·40	40·0	60·0	70·21	51·7	399	V	”	V	”	”
	34·64	42·47	...	0·25	21·40	0·81	0·08	0·35	50·0	50·0	51·70	63·8	440	V+C	”	C+V	”	”

1·0 silicate do. do. do.	36·69	6·99	...	0·04	53·43	2·01	0·19	0·65	6·2	93·7	47·06	48·7	428	C+V	Grey	C	Grey	No threads
	36·88	8·47	...	0·05	51·83	1·95	0·19	0·63	7·7	92·2	50·13	49·0	410	C+V	„	C	„	„
	37·17	9·84	...	0·06	50·23	1·90	0·18	0·62	9·1	90·9	58·09	45·3	380	C+V	„	C	„	„
	37·67	12·38	...	0·07	47·32	1·79	0·17	0·60	11·8	88·2	52·22	58·9	363	C+V	„	C	„	„
	38·10	14·64	...	0·08	44·75	1·68	0·16	0·58	14·3	85·7	66·57	63·2	349	V	„	C+V	„	Threads
	38·92	18·47	...	0·11	40·29	1·52	0·14	0·55	18·9	81·1	66·26	64·5	347	V	„	V	„	„
	39·56	21·63	...	0·13	36·66	1·38	0·13	0·51	23·1	76·9	56·07	74·6	355	V	„	V	„	„
	39·86	23·00	...	0·13	35·06	1·32	0·13	0·50	25·0	75·0	66·01	48·4	361	V	„	V	„	„
	40·34	25·44	...	0·14	32·27	1·22	0·11	0·48	28·6	71·4	88·54	63·1	377	V	„	V	„	„
	40·93	28·34	...	0·16	28·92	1·09	0·10	0·46	33·3	66·7	63·61	56·5	400	V	„	V	„	„
	41·86	31·94	0·91	0·18	23·25	1·03	0·08	0·75	40·0	60·0	61·46	55·3	430	C+V	„	C+V	„	Some threads
	43·15	33·39	0·96	0·19	20·56	0·93	0·07	0·75	43·9	56·1	50·51	106·1	461	C+V	„	C+V	„	„
1·5 silicate do. do. do.	44·94	0·45	...	...	51·80	1·95	0·19	0·67	0·3	99·7	96·75	63·8	431	C.	Grey	C	Grey	No threads
	45·67	3·17	0·08	0·02	48·38	1·83	0·17	0·68	3·2	96·8	43·80	96·8	417	C.V+V	„	C.V	„	„
	46·74	7·13	0·19	0·04	43·39	1·67	0·16	0·68	7·7	92·3	60·16	79·3	377	V+C.V	„	V+C.V	„	Some threads
	47·66	10·55	0·29	0·06	39·09	1·52	0·14	0·69	12·0	88·0	100·0	100·0	358	V	„	V	„	Threads
	48·11	12·23	0·34	0·07	36·98	1·45	0·13	0·69	14·3	85·7	100·0	100·0	357	V	„	V	„	„
	48·95	15·38	0·43	0·08	33·03	1·32	0·12	0·69	18·9	81·1	92·79	87·3	362	V	„	V	„	„
	49·64	17·94	0·51	0·10	29·81	1·21	0·10	0·69	23·1	76·9	87·62	93·2	379	V	„	V	„	„
	49·94	19·05	0·54	0·11	28·41	1·16	0·10	0·69	25·0	75·0	59·76	65·8	388	V	„	V	„	„
	50·46	21·00	0·60	0·12	25·96	1·07	0·09	0·70	28·6	71·4	49·06	79·2	396	V	„	V	„	„
	51·10	23·39	0·67	0·13	22·95	0·98	0·08	0·70	33·3	66·7	70·17	80·0	404	V	„	V	„	„
	51·91	26·40	0·75	0·15	19·17	0·85	0·07	0·70	40·0	60·0	77·16	77·1	412	V	„	V	„	„
	52·96	30·30	0·87	0·17	14·26	0.68	0·05	0·71	50·0	50·0	72·73	90·0	422	V	„	V	„	„

Lime and Alumina Silicate.—The alumina is regarded as a base. With regard to the ratio of the oxygen in the alumina to that in the other bases, the following were the results as to fusibility :—

	Percentage of Alumina.	Calories.
3·0 silicate . .	0·0	396
	0·1	346
	0·3	374
	1·0	407
2·5 silicate . .	0·0	446
	0·2	347
	0·9	390
	2·0	408
2·0 silicate . .	0·0	472
	0·35	350
	2·0	408
1·5 silicate . .	0·0	431
	0·5	357
1·5 silicate . .	2·0	412
	3·0	423
1.0 silicate . .	0·2	428
	0·7	347
	2·35	461
0·7 silicate . .	0·5	447
	1·2	355
	3·0	440
0·5 silicate . .	1·5	406
	1·75	369
	2·98	423

Manganous Oxide and Lime Silicates.—The mono-silicate is the most infusible, the 1·5 the most fusible, the bisilicate lying between the two. The first of these fuses with 366 calories, the second with 345, and the bisilicate with 351; all three containing about 80 MgO and 20 CaO. The 2·5 silicate of manganous oxide requires for its fusion 387 calories, or 32 calories more than the most fusible lime manganese silicate.

In the case of the trisilicate, the lowest fusion point is 371 calories, an increase in the manganous oxide considerably increasing the fusion point.

Silicates of Lime, Alumina, Magnesia, and Manganous Oxide.—Of the three latter substances the alumina has, in relation to oxygen and weight, the greatest power. With the exception of the 1·5 silicate of lime and manganese, the heat minima produced by lime lie considerably lower than those produced by the other two bases. The relative positions of magnesia and manganous oxide are hard to determine; in the 2·0 and 2·5 silicates magnesia has a more powerful action than manganous oxide, while in the 1·0 and 1·5 silicates the latter has greater influence than the magnesia. The magnesia does not produce such low minima as the manganous oxide.

The experiments showed that, hitherto, too much influence has been supposed to be exerted by the manganous oxide with regard to its influence on the fusibility of slags. It is true that it causes them to be more thin-fluid, but the action on the furnace walls becomes much greater.

Ternary Silicates ($CaO + MgO + Al_2O_3$) :—

	Percentage of Alumina.	Calories.
1·5 silicate (9 CaO + 4 MgO)	0·0	411
	5·0	373
	10·0	362
	25·0	400
2·0 silicate	0·0	376
	10·0	387
	22·0	423
2·5 silicate (7 CaO + 2 MgO)	0·0	362
	0·2	369
	15·0	303

The mean amount of heat required for the fusion of 74 blast-furnace slags was 388 calories (340 to 463). Of these 27 were mono-silicates, requiring 396 calories; 43 bisilicates, requiring 382; and 4 trisilicates, each of these latter requiring 392 calories.

The Mineralogical Constitution of Slags.—J. H. L. Vogt * adds to the knowledge of the minerals crystallising in slags, and the circumstances on which the formation of the various minerals depends. By careful experiments he has arrived at several important conclusions, of value both for theoretical and practical metallurgy. The mineralogical investigation was made with material, quantitative analyses of which were at hand. In all, 195 analyses are given, more than 90 being specially made for the purpose by Professor Åkerman.

The following minerals have been observed in blast-furnace slags :—Of the pyroxene group, augite, enstatite, wollastonite, rhodonite, an asymmetric pyroxene resembling babingtonite; mica; of the olivine group, olivine proper, fayalite, tephroite, monticellite-like olivines rich in lime, and fayalite rich in zinc oxide; willemite; a hexagonal calcium silicate; melilite, gehlenite, and a new tetragonal mineral free from alumina and relatively rich in silica and lime; spinel and magnetite; calcium, manganese, and iron sulphides; cuprite; metallic copper; and free ferrous oxide.† In the slags (enamel-slags) very rich in silica, compounds appear only as small globulites and crystallites. Of the substances mentioned, the asymmetric pyroxene resembling babingtonite, the hexagonal calcium silicate, and the tetragonal mineral, have hitherto not been met with in nature.

A comparative study of the analyses shows that the formation of minerals in the molten mass is dependent on the chemical composition of the average mass; the minerals being formed by chemical action on a large scale. The results of the chemical investigation regarding the affinity between silica, lime (with some soda and potash), magnesia (with ferrous oxide), and alumina are shown graphically by the author; the oxygen ratio being marked off on the ordinate axis and the proportion between magnesia and lime on the abscissa axis. It is thus seen that with a proportion of 100 to 55 per cent. of calcium silicate to 45 per cent. of magnesium-iron silicate, gehlenite is formed, provided that the silica ratio does not exceed 0·8; from that amount to 1·2, melilite is formed; and from that to 1·4, the new tetragonal mineral. In all these cases mixtures rich in magnesia give olivine silicate. If the silica ratio exceeds 1·5, mixtures rich in magnesia crystallise as enstatite; mixtures with 30 to 75 per cent. of calcium silicate, as augite; and lastly those still richer in calcium as hexagonal calcium silicate (silica ratio 1·5 to 2) or as wollastonite (silica ratio 2 to 2·5). Mixtures containing more silica than this give enamel-like slags.

---

* *Jern-kontorets Annaler*, vol. xl. pp. 232–320. Compare *Journal of the Iron and Steel Institute*, 1885, p. 695.

† G. J. Brush (*American Journal of Science*, 1865, vol. xxix.) noted the occurrence of diopside.

Analysis of Hungarian Blast-Furnace Slag.—Dr. E. Prziwoznik* publishes the following analysis of blast-furnace slag from Betlér:—

Silica.	Alumina.	Manganous Oxide.	Ferrous Oxide.	Lime.	Magnesia.	Potash.	Soda.	Calcium Sulphide.	Calcium Phosphate.	Total.
50·13	9·61	3·63	1·35	15·00	16·56	1·34	1·15	1·05	0·11	99·93

The Utilisation of Blast-Furnace Slag.—E. Chabrand† gives the following comparative analyses of some blast-furnace slags and cements, to show that the main constituents were the same in both cases, the difference in composition consisting merely in the relative percentages:—

	SiO_2.	Al_2O_3.	CaO.	MgO.	FeO.	MnO.	SO_3.	Other Constituents.
Slags.								
Ybergues . . .	35·00	12·85	48·50	1·45	0·50	1·50	...	0·30
Longwy, forge pig .	39·77	17·58	38·92	...	3·71	...	...	...
Longwy, foundry pig .	36·00	17·98	46·02	...	...	...	...	...
Hæmatite pig . .	35·00	15·00	46·40	2·00	0·10	0·10	...	1·35
Cements.								
Boulogne . . .	24·00	7·20	59·40	...	...	...	...	...
Desvres . . .	24·03	8·52	61·31	...	...	...	...	...
Samer	24·70	8·25	60·50	...	...	...	...	...
Portland . . .	22·61	19·29	51·63	...	...	...	...	...
Wassy	22·35	15·60	51·30	0·75	...	...	2·90	7·10 Loss on ignition.
St. Ismier . . .	24·60	15·20	56·30	0·95	...	...	1·10	1·85 Loss on ignition.
Cahors	28·20	14·25	50·65	1·05	...	...	...	...

---

* *Berg- und Hüttenmännisches Jahrbuch der k.k. Bergakademien*, vol. xxxiv. p. 59.

† *Génie Civil*, vol. viii. pp. 6–7.

The author then describes Farinaux's method of manufacturing cement from blast-furnace slag by the addition of 60 to 80 per cent. of quicklime. The lime and slag are intimately mixed in the proper proportions, producing a cement which, after being set for fifteen days, becomes as hard as stone. One per cent. of sodium carbonate should be added to the lime. This gives the cement greater rapidity of setting and increased hardness. The cost of manufacture is estimated at 8s. 6d. per ton.

Blast-Furnace Slag Cement.—The relative value of Portland cement, as compared with that produced from blast-furnace slags, has been made the subject of an investigation by C. Schumann.[*] The results he obtained are as follows:—Slag cement does not harden nearly so rapidly as Portland cement, and it is more permeable. Portland cement will stand nearly twice the pressure that slag cement can resist. While the tensile strength of the Portland cement increases rapidly on drying in air, reaching as much as 64 per cent. increase over that hardened for twenty-eight days under water, slag cement, on the other hand, does not increase in strength after removal from the water. Portland cement will stand for equal strength the admixture of twice the quantity of sand that can be added to slag cement.

V.—*FOUNDRY PRACTICE.*

Modifications in Foundry Practice.—J. Möller proposes to use for moulds for ingot iron castings mixtures consisting of from 24 to 30 litres of finely-powdered, well-burnt pure clay, 100 cubic centimetres of sugar, 2 litres of water, and one-seventh litre of paraffin.

G. L. R. Stenay dries moulds by passing a smoky flame through them, allowing the products of combustion to escape through the holes in the mould.[†]

The Greiner and Erpf Cupola.—This cupola is so arranged that while blast is introduced through a set of tuyeres in the ordinary manner, another series of much smaller tuyeres is placed in the form of a spiral, from low down in the neighbourhood of the main tuyeres almost to the throat of the cupola. These smaller tuyeres are supplied with blast of much lower pressure than that which passes to the larger ones. The furnace is adopted at many works in Austria-Hungary and in Germany; and a cupola arranged in this manner showed a saving of 33 per cent. of coke, when compared with the furnace as arranged originally.*

---

[*] *Chemisches Reportorium*, vol. x. p. 25.

[†] *Dingler's Polytechnisches Journal*, vol. cclix. pp. 300–307.

---

* *Stahl und Eisen*, vol. vi. p. 97.

PRODUCTION OF MALLEABLE IRON.

Forsberg's Swedish Hearth.—Professor J. von Ehrenwerth,* in discussing the value of the Forsberg 3-tuyere hearth, remarks that by using the waste heat from the sides to heat the incoming blast, a blast temperature of from 90° to 110° C. is attained. The quality of the iron produced in the Forsberg hearth is stated to be of much better quality than that produced in the 2-tuyere hearths, and without diminishing the quality of the product obtained, less skilled workmen may be employed. Results which have been obtained in practice are tabulated as showing the truth of the above statements, and a drawing of the hearth accompanies the paper.

The Beasley Puddling Process.—In a paper read before the Society of Engineers Mr. P. S. Justice described the Beasley puddling process, which, it is stated, has now been successfully employed for over two years. It consists in using a fettling composed of one-third puddling cinder and two-thirds blue-billy, which are reduced to powder by passing them between rollers. To this mixture five parts by weight of hydrochloric acid are added, the acid being first diluted by an equal quantity of hot water. The whole is allowed to stand for three or four days, during which period sulphuretted hydrogen and chlorine are evolved, and then from 20 to 30 per cent. of lime and 3 to 5 per cent. of salt are added, the quantities being dependent on the nature of the pig iron to be treated.

The furnace having been previously fettled, some of this mixture is painted over the surface, and two or three shovelsful of a similarly treated mixture of one-third ore and two-thirds hammer-scale are charged in in the dry state. This method of treatment is stated to cause the elimination of the greater portion of the phosphorus and to greatly increase the out-turn.

---

* *Stahl und Eisen*, vol. vi. pp. 314–317.

The Küpper Puddling Furnace.—This furnace has a length of 21 feet and a breadth of 7½ feet at the fireplace, and 6 feet 8 inches at the working hearth; with a height of 5 feet. The hearth consists of two divisions, but these are in complete communication with each other, and each has a door at either side. Two puddler's-helpers can work at a side at the same time without interfering with each other. A blast is introduced beneath the fireplace, part of the air passing up through the grate and a part through holes in the firebridge. Many such furnaces have been in use at different works for some time past, and have given very good results.*

Dephosphorisation of Puddled Iron.—Dr. T. Tscheuschner † discusses the possibility of the removal of phosphorus from puddled iron. Many years since he carried out a series of investigations the results of which he now publishes, in which various charges of known chemical composition were smelted in the blast-furnace, and the products obtained submitted to analysis.

The experiments were carried out at one of the chief works in the Rhenish-Westphalian district, and the following are analyses of the ores which were treated:—

	Red Hæmatites.			
	I.	II.	III.	IV.
Ferric oxide	58·61	52·58	56·40	44·95
Manganese oxide (Mn_3O_4)	trace	trace	trace	0·00
Lime	0·31	0·40	trace	($CaCO_3$) 33·31
Magnesia	0·39	0·00	0·52	($MgCO_3$) 1·68
Alumina	7·12	8·36	8·46	3·00
Silica	25·25	24·48	25·00	13·39
Phosphoric anhydride	0·30	0·28	0·14	0·19
Sulphur	0·22	0·02	0·15	0·19
Water, loss at 120° C.	6·45	11·34	6·40	3·40
Loss on ignition	0·78	2·70	3·21	...
Totals	99·43	100·16	100·28	100·11

---

* *Stahl und Eisen*, vol. vi. p. 362.

† *Chemiker Zeitung*, vol. x. pp. 617–618 and 645–646.

	Brown Hæmatites.			
	I.	II.	III.	IV.
Ferric oxide	46·72	41·90	30·28	43·25
Manganese oxide (Mn_3O_4)	trace	7·00	5·14	9·51
Lime	0·00	2·70	0·58	1·34
Magnesia	0·66	0·40	1·92	0·57
Alumina	12·08	6·99	7·94	9·77
Silica	19·53	18·21	35·44	14·90
Phosphoric anhydride	0·84	1·47	0·18	0·19
Sulphur	0·07	0·00	0·31	0·02
Water, loss at 120° C.	9·91	12·98	9·49	9·55
Loss on ignition	10·90	6·87	9·51	11·58
Totals	100·71	98·52	100·79	100·68

	Clay Ironstone.	Spathic Iron Ore.	Bog Iron Ore.		Reheating Furnace Slag.
Ferrous carbonate	72·53	47·00	...	...	...
Ferric oxide	...	...	36·05	33·97	10·69
Ferrous oxide	...	...	...	...	61·83
Manganese carbonate	7·36	10·46	...	...	...
Manganese oxide (Mn_3O_4)	...	...	8·72	17·06	...
Manganous oxide	...	...	...	...	0·42
Calcium carbonate	1·04	2·87	...	...	...
Lime	...	...	1·48	0·72	trace
Magnesium carbonate	0·04	4·05	...	...	...
Magnesia	...	...	2·01	0·96	0·73
Alumina	4·20	6·50	6·63	2·88	0·00
Silica	11·46	21·75	21·84	14·34	25·52
Phosphoric anhydride	0·12	...	1·03	0·89	1·02
Iron sulphide (FeS_2)	...	6·30	...	...	...
Sulphur	0·41	...	0·11	0·04	0·14
Moisture	1·64	0·71	18·00	16·04	...
Loss on ignition	1·20	...	3·59	13·04	...
Totals	100.00	99·64	99·46	99·94	100·35

The ores were mixed for smelting as follows:—

	I.	
	Volume.	Per Cent. by Weight.
Red hæmatite, I.	14	43·3
,, ,, II.	8	16·7
Brown hæmatite, I.	7	13·5
,, ,, II.	3	5·2
Bog iron ore, I.	9	13·2
Spathic iron ore	2	4·4
,, ,,	6	12·7
Totals	49	109·0*

* 100·0 in original.

	II.	
	Volume.	Per Cent. by Weight.
Red hæmatite, I.	4	10·8
,, ,, III.	13	28·0
,, ,, IV.	8	18·5
Brown hæmatite, III.	5	9·7
,, ,, IV.	4	8·7
Clay ironstone	9	19·4
Spathic iron ore	2	4·9
Totals . .	45	100 0

	III.	
	Volume.	Per Cent. by Weight.
Red hæmatite, III.	15	29·6
,, ,, IV.	15	31·9
Clay ironstone	15	29·5
Bog iron ore, II.	5	9·0
Totals . .	50	100·0

These mixtures were treated in the blast furnace with the addition of the following amounts of limestone:—I. 40 per cent.; II. 32 per cent.; III. 32 per cent.

The limestone had the following percentage composition:—

$CaCO_3$.	$MgCO_3$.	Al_2O_3.	Fe_2O_3.	SiO_2.	P_2O_5.
93·94	2·62	0·76	0·54	2·82	trace

The slags produced from each of these charges were composed as follows:—

	I.	II.	III.
	Per cent.	Per cent.	Per cent.
Silica	45·50	43·01	38·20
Lime	31·81	34·05	41·00
Magnesia	1·79	2·26	1·44
Ferrous oxide	1·93	1·82	1·12
Manganous oxide	2·93	3·76	4·27
Alumina	13·54	12·84	11·35
Calcium sulphide	1·95	3·30	2·53
Phosphoric anhydride . .	trace	trace	trace
Totals . .	99·45	101·04	99·91

The pig iron proved on analysis to have the composition :—

	I.	II.	III.
	Per cent.	Per cent.	Per cent.
Iron	93·83	96·05	91·98
Silicon	1·22	1·12	1·22
Phosphorus	0·67	0·31	0·32
Sulphur	0·22	0·22	0·28
Manganese	0·00	0·00	1·38
Carbon and loss	4·06	2·30	4·82
Totals	100·00	100·00	100·00

I. was grey, II. slightly mottled, and III. strongly mottled.

Each of these pig irons was submitted to puddling, separate furnaces being used, No. I. being treated for fine grained iron (puddled steel), and Nos. II. and III. for fibrous iron. Schafhäutl's Powder (a mixture of pyrolusite and salt), was used in the puddling of I. and II. No. I. yielded a bloom of fine grain; No. II., an iron which was slightly fibrous; No. III., a good long-fibred iron. They were found to contain the following percentages of phosphorus and silicon :—

	I.	II.	III.
	Per cent.	Per cent.	Per cent.
Phosphorus	0·15	0·12	0·12
Silicon	0·25	0·28	0·20

The cinder formed towards the end of the puddling contained :—

	I.	II.	III.
	Per cent.	Per cent.	Per cent.
Ferrous oxide	60·50	55·09	60·57
Ferric oxide	7·01	9·11	13·20
Manganous oxide	5·51	8·46	6·32
Lime	1·08	trace	trace
Magnesia	0·00	trace	0·56
Alumina	1·45	0·00	2·19
Silica	16·60	22·30	13·45
Phosphoric anhydride	6·60	3·71	2·80
Ferrous sulphide	1·85	1·97	0·80
Totals	100·60	100·64	99·89

Each puddled iron was packeted, welded, and rolled to puddled bar, which was again analysed, and showed :—

	I.	II.	III.
	Per cent.	Per cent.	Per cent.
Phosphorus	0·06	0·08	0·09
Silicon	0·24	0·28	0·18

It will be observed that from the pig iron and puddled iron, which were the richest in phosphorus, the bar iron poorest in phosphorus was obtained; and it will also be seen that each of the three bar irons are considerably freer from phosphorus than the puddled irons from which they were produced. It was found that the phosphorus had passed into the reheating furnace slag, which on analysis gave:—

	I.	II.	III.
	Per cent.	Per cent.	Per cent.
Ferrous oxide	59·00 } =51·60 Fe	44·86 } =45·60 Fe	58·89 } =51·40 Fe
Ferric oxide	8·01	15·31	7·98
Manganous oxide	trace	trace	0·30
Lime	trace	trace	trace
Magnesia	0·43	0·46	trace
Alumina	5·51	7·69	0·00
Silica	25·82	30·53	31·08
Phosphoric anhydride	1·12	0·77	0·60
Ferrous sulphide	0·34	0·10	0·25
Totals	100·23	99·72	99·10

The author points out that the dephosphorisation of the iron during the welding process is probably due to the separation by liquation of a phosphide of iron of definite composition.

FORGE AND MILL MACHINERY AND PLANT.

A 4000-ton Hydraulic Forging Press.—This gigantic machine is being constructed for Charles Cammel & Co. by Messrs. Davy Brothers. It is illustrated and described in *Engineering.*[*]

Among the large hammers in European works are the following:—Messrs. Schneider have a 100-ton hammer, the St. Chamond Works an 80-ton, Woolwich a 40-ton, Krupp a 60-ton at work, and a 150-ton in course of erection. The great cost of installation of such large hammers has deterred English steelmakers from making much advance, and besides this, they have felt that the hydraulic press was more suitable for the production of large forgings. Except in two instances, the efforts made to substitute the press have met with only partial success. The press has been proved to make the best forgings; and the cost of installation is less in proportion to the weight of forgings made. The moderate height of a press permits the use of overhead travelling cranes, so that the furnaces can be ranged along the sides of the forge with one press to serve all six or eight. It is less costly to keep in working order than a large hammer, less liable to breakdowns, and the supposed inherent slowness of action has been overcome.

Rolling Steel Wire.—The chief feature of Boecker's invention for rolling steel wire of No. 9 gauge consists in using two sets of rolling-trains, which are arranged behind one another. The wire goes in a straight line from the first train to the second, the rolls of the latter having a greater velocity. The formation of loops in the wire is thus avoided while it is passing from one pair of rolls to the other. It is said that there is no difficulty in rolling steel wire down to No. 9 gauge, or 3·76 millimetres, by this method.[†]

---

[*] Vol. xli., p. 393.

[†] *Engineering and Mining Journal*, vol. xli. p. 210.

Fuel Consumption in Rolling Wire Rods.—At the Bussery and Verdié Works, at Lorette, France, a Corliss engine built by Schneider of Creusot has been driving a train for rolling steel wire rods during four years. A series of tests have recently been made, extending over ten days, to ascertain the fuel economy of the engine. The latter has a 26·59-inch cylinder, and a 49·2-inch stroke, and makes 61 to 64 revolutions a minute. During the trial the billets were uniform in size, and the same size of rods was rolled. A series of diagrams taken with a Richards indicator showed that the cut off varied from 0·04 to 0·1 of the stroke. The indicated horse-power was 156; the consumption of water per ton per horse-power was 16·75; and the consumption of coal was 2·5 lbs. per hour per horse-power, The coal had 15 per cent. of ash.*

Leather Belt for Driving Fast-Roll Trains.—It is stated that at the Rothe Erde Works, on a fast train, the driving-wheel of which makes 560 to 580 revolutions per minute, a four-ply leather driving-belt was put on with the following favourable results, considering the high speed: It was put on on the 9th of August. On the 10th, 450 millimetres of slack were taken out; on the 11th, 80 millimetres; on the 12th, 300 millimetres; and on the 20th of September, 130 millimetres. Up to the beginning of December it did not stretch any more, although the train was double-shift, except Sundays. Similarly good results were obtained at the rolling-mills of A. Herwig, at Dillenburg, where a belt 800 millimetres broad and 37 millimetres thick showed 600 millimetres slack between the 3rd of August and the 14th of September.†

Electric Lighting in Rolling-Mills.—A paper on this subject was read before the South Staffordshire Institute of Iron and Steel Works Managers, by Mr. G. B. Wright. It might, he said, have been surmised that the iron rolling-mills of South Staffordshire, with their low-pitched roofs, would have been the last field wherein to look for the profitable use of the electric light. There are, however, several important works where it has been adopted. Sheet iron is the staple manufacture of the district, and it was at one time thought impossible to supply the roller with the electric light just where the gas jet is always placed. Such difficulties, however, occur only with the arc system of electric lighting, and have been wholly removed by the incandescent lamp system. At the large steelworks throughout the country the arc system is mostly employed, but in Staffordshire, except for the incandescent lamp, the gas jet would have to be retained. There is no better example of the successful application of the incandescent light than in the case of the Swan Garden Ironworks, Wolverhampton. The gas was shut off, and the new light started about a month before Christmas, and though the days have been so short that the light has been required as much as 18 and 19 hours out of the 24, all has gone on well. For sheet rolls and shears the light is all that is required, for the stocktaker's examination it answers admirably, and for yards and wharves, though less brilliant than the arc lamp, it serves exceedingly well. It is absolutely free from danger of shock, the electric current being of too low an intensity to be dangerous. The current is generated by two "compound wound" dynamos, which allow of any number of the lights being turned off without detriment. There are 380 lamps upon the two machines, 60 of them being single lamps of 95 volts, and 320 running in pairs at 48 volts. The dynamos are driven at 950 revolutions per minute by an ordinary well-built, high-pressure, horizontal engine, running at 90 revolutions, and supplied by steam at 40 lbs., raised by the waste heat from the heating and puddling furnaces. The apparatus is in charge of an ordinary engine-driver.

---

* *Engineering and Mining Journal*, vol. xli. p. 151.

† *Stahl und Eisen*, vol. vi. p. 67.

At the Monmoor Ironworks, Wolverhampton, the incandescent system is also in use. One-half of the extensive works has thus been lighted up for fifteen months past, and the installation is running as steadily now as the day it started. In this case the dynamo generating the current is, with a small engine to drive it, placed upon the top floor of the mill-engine house, and the engineer for the time looks after it without trouble. A third example is that at the new sheet mill at Tividale. Here the dynamo is driven from the fly-wheel of a small engine which drives a pair of edging tools, and which the mill engineer also looks after.

At these works there is no provision for storing the electricity, nor has the need of it been felt. In several other large works storage cells are employed, in order that the current which had been produced in the day may be used during the night. But in ironworks storage is practically unnecessary. The cost of maintenance is, in each of the examples given, well below the cost of gas.

Soaking-Pits for Tyres.—At the Osnabrück Steelworks soaking-pits are employed for the slow and uniform cooling of tyres after rolling. The pits are constructed in the ground in the usual manner, and are of such a size that they hold twelve tyres, one placed on top of the other. The tyres are taken from the rolls to the pits by means of travelling cranes, and are left to cool for three or four days in the closed pits. Experiments have shown that tyres cooled in this way have 50 per cent. greater strength than those cooled in the ordinary manner in ashes or simply exposed to air.*

Safe Working Pressure for New Boilers.—The following table to be used in fixing the working pressure of new boilers is given by the *Locomotive*. It also shows the proper pitches for different thicknesses of plates, both single and double riveting. The pressures given by the table are not so high as are allowed by the rules of the United States Board of Supervising Inspectors, but these are somewhat greater than can be safely carried after a boiler has been in use for some time. The pressures are based on a tensile strength for steel of 60,000 lbs. and for iron of 50,000 lbs. per square inch of section :—

Thickness of Plates. Inch.	Diameter of Rivets. Inch.	Pitch.		Material.	Safe Working Pressure in Pounds per Square Inch for Shells with Longitudinal Seams Double Riveted.						
		Single Riveting. Inches.	Double Riveting. Inches.		36-inch Diam.	42-inch Diam.	48-inch Diam.	54-inch Diam.	60-inch Diam.	66-inch Diam.	72-inch Diam.
$\frac{1}{4}$	$\frac{5}{8}$	2	3	Iron Steel	115 135	100 115	85 100	70 85	... ...	... ...	... ...
$\frac{5}{16}$	$\frac{11}{16}$	$2\frac{1}{16}$	$3\frac{1}{8}$	Iron Steel	135 160	115 135	100 120	85 105	80 95	... ...	... ...
$\frac{3}{8}$	$\frac{3}{4}$	$2\frac{1}{8}$	$3\frac{1}{4}$	Iron Steel	160 190	135 160	120 140	105 125	95 115	85 100	80 95
$\frac{7}{16}$	$\frac{13}{16}$	$2\frac{3}{16}$	$3\frac{3}{8}$	Iron Steel	190 220	155 185	135 160	125 145	110 130	100 120	95 110
$\frac{1}{2}$	$\frac{7}{8}$	$2\frac{1}{4}$	$3\frac{1}{2}$	Iron Steel	210 250	170 205	150 180	140 165	125 150	115 135	105 125

It is not advisable to make 60-inch shells less than $\frac{5}{16}$, and 66- and 72-inch shells less than $\frac{3}{8}$ inch thick, and for each thickness of steel plate the rivets, if of iron, would better be $\frac{1}{16}$ inch larger than are given in the table.

---

* *Stahl und Eisen*, vol. vi. p. 65.

THE PRODUCTION OF STEEL.

CONTENTS.

	PAGE		PAGE
I. Direct from Iron Ore . . .	331	III. The Open-Hearth Process .	336
II. By the Carburisation of Malleable Iron	332	IV. The Bessemer Process . .	338

I.—*DIRECT FROM IRON ORE.*

Indian Steel.—Superior steel, including wootz, was formerly made from the ores of Bajaur, near Peshawur, and in Kachh; probably also in Assam, where large cannon were made, and in Gualior, Bijawar, and Indor; these places and provinces comprise the whole of the seats of old steel manufacture in Northern India that are now known. In Southern India the probable seats were Palaman (Bengal), Jashpur and Gangpur, Madgole, Sambalpur, Narsingpur, Surat, and various places in the Konkan, Haidarabad territory, Satara, Maisur territory, Kadapa, and perhaps several places in the extreme south of the peninsula.

The essential points in wootz making seem to have been the use of iron of two ores, one magnetic sand or magnetite obtained by mechanical separation from rock, the other a rich laterite; an enormous amount of fuel, perpetual reconstruction of furnaces, certain charcoals, and leaves and roots of certain plants; possibly also small quantities of some slags and fluxes. Some of the charcoals used were—bamboo charcoal, sal (*Shorea robusta*), bijasal (*Dipterocarpus marsupium*), mhawa (*Bassia latifolia*), teak, dhao (*Conocarpus latifolia*) and ker (*Acacia catechu*); also green leaves of the *Convolvulus laurifolia* or *Ipomoea*, stems of the *Cassia auriculata*, and leaves of the ak or madar (a large Asclepiad, *Calotropis gigantea*), as well as the charcoal of its roots.

In olden times, when fuel was plentiful, the chief requisite was evidently the magnetic iron sand or magnetite, capable of mechanical reduction; and apparently it was also indispensable, while much of the rest may have admitted of substitutes under some variety of treatment. There are doubtless theories that some special excellence may have been locally due to an amount of ferrous oxide, to manganiferous or titaniferous ores, or to slightly calcareous ores; but none of these are fully proved. There may have been some special secrets of treatment or manufacture, but everything points to excessive purity of iron, judicious blending, and selected charcoals, as the chief matters on which general excellence was based.*

II.—*BY THE CARBURISATION OF MALLEABLE IRON.*

The Manufacture of Crucible Steel.—M. Böker † describes the process for the manufacture of crucible steel as pursued in German works. Dr. Wedding, in a preface to the paper, points out that the manufacture of crucible steel is carried on largely in Germany, and that although the steel so produced was at one time not equal to that manufactured in Great Britain, at present it not only equals but exceeds in quality British crucible steel sold at the same price. Though the steel may be of even better quality, Professor Wedding remarks that those who have used a particular variety of metal get so accustomed to the particular treatment it requires that they will have nothing to do with a metal requiring, it may be, somewhat different treatment, and consequently German steel is not so much employed as, from its quality and its price, it deserves to be.

Crucible steel to be of value for the special purposes to which such metal is put must fulfil the following conditions:—

1. It must harden well. 2. It must possess toughness after hardening. 3. It must be easy to work before hardening.

By the term toughness the author refers chiefly to the property which the steel possesses of resisting the separation of its particles after it has been hardened.

Effects of hardening steel are changes in the limit of elasticity, and in the tensile strength. All the foreign elements present in the steel are of influence on the various properties mentioned above, and the one which plays the greatest part is carbon.

In order to produce a steel out of which may be manufactured tools which shall retain a good cutting edge, it is necessary that the steel should contain a high percentage of carbon, the higher the better, as long as certain limits, dependent on the nature of the metal, are not exceeded. These limits are also dependent on the change of form which steel undergoes on hardening, and the consequent tension which is thereby introduced, which tends to induce the splitting of the metal. To avoid this it is necessary that the hardened steel should be tempered.

---

* *Journal of Science*, vol. vii. pp. 710–719.

† *Stahl und Eisen*, vol. vi. pp. 33–42.

In choosing a good tool steel, the statement that one high in carbon must be selected is modified—

1. By the quality of the steel. 2. By the shape of the tool to be produced, and the purposes for which it is to be employed. 3. The skill of the workman who works up the steel into the desired form.

In choosing a metal to be converted into crucible steel, it is necessary to examine its chemical composition chiefly as regards the percentages it may contain of phosphorus, sulphur, copper, silicon, and manganese. Other elements, with the exception of chromium and tungsten, are rarely present in quantities sufficient to produce any marked effect.

Phosphorus, sulphur, and copper occur in finished steel in almost the same quantities as they were present in the raw material, and the extent to which they are present in a raw material shows, therefore, at once whether it is suitable for the desired purpose or not.

Sulphur may be introduced into the steel from the fuel, and from materials composing the crucible, from which source the silicon in the steel produced is chiefly derived. After referring to the action of the melting pot, to the method of producing cement steel from Swedish bars, to the fusion of the cemented bars, and the working up of the crucible steel, the author points out that by heating under reducing conditions, and then hammering, burnt steel may to a greater or lesser extent be brought back to its original condition.

In order to determine the effect of carbon on the change of form after hardening, three rings of a definite size were heated to redness and then plunged into water, and remeasured. One ring contained 0·6 per cent. carbon, and this had contracted very little; the second contained 1 per cent. of carbon, and the diminution in its diameter after hardening was considerably greater than in the case of the ring with 0·6 per cent. carbon; the third ring contained 1·5 per cent. carbon, and the diminution in diameter was very considerable. Thus it is evident that the percentage of carbon in the steel will vary greatly with the use to which it is to be put; and in order to facilitate reference, it is customary to class crucible steels in various ways. The Remschied Berg Steel Company classifies the different varieties as follows:—

Number.	Carbon per cent.
8	0·8
9	0·9
10	1·0
11	1·1
13	1·3
15	1·5

And in connection with this classification tungsten steel is designated as No. 20, in order to show its considerably greater hardness as compared with carbon steels.

In order to prevent the hardened metal cracking on working it up, it is necessary to temper it, and this again is in connection with the percentage of carbon it contains. Thus, to take the classification adopted above, practice shows it is necessary to temper the different steels so as to obtain the following colours:—

Percentage of Carbon.	Colour.
0·8	blue
0·9	violet grey
1·0	carmine
1·1	brick red
1·3	dark yellow
1·5	straw
Tungsten steel	white

In working up the steel for the manufacture of tools, it is well to use a charcoal fire, as not only is the temperature lower but the atmosphere more reducing than with other fuels, and the steel can be heated more gradually and more uniformly than would otherwise be possible, and unskilled workmen are less liable to spoil the steel. A coke fire, though not so good as charcoal, is much better than one of ordinary coal, especially if the coal be a caking variety, as is usually the case. Besides the liability to a too intense heat being obtained, the coal usually contains a certain quantity of sulphur, and this, by combining with the iron, forms places in the steel which will not harden. These spots on steel heated as above, are, however, usually due to the action of residual and burnt air, and this may be easily proved by experiment.

After heating the steel it should be shaped as rapidly as possible in order to avoid too frequent reheating. Hammering the steel causes tension to be produced, and it should consequently never be hardened directly after hammering, but should be allowed to cool slowly, and then heated afresh before hardening it.

The author, after describing the process of hardening, passes to the consideration of tungsten steel. Tungsten is specially useful in the production of steel capable of assuming a high degree of hardness, while simultaneously increasing the toughness. Tungsten steel implements retain their cutting edges in a remarkable degree, and on hardening they alter their form but little. Unfortunately it is not easy to work before hardening, and its use has therefore remained somewhat limited. It is specially useful for the construction of magnets, in consequence of the fineness of its grain.

Castings from Wrought Iron or Steel.—At the Pittsburg meeting of the American Institute of Mining Engineers, Mr. P. Oestberg explained the main features of the manufacture of "Mitis" castings.

The moulding material (U.S. patent, No. 317062) is made from pure fireclay alone, hard-burnt, finely ground, and mixed with sugar or treacle as binding material, which does not, like clay-water, impair the fusibility.

In the furnace (U.S. patent, No. 321840) used for melting the wrought iron, petroleum is the fuel employed, the furnace being constructed on the same principle as a common petroleum lamp. A constant surface of oil is exposed, the area of the chimney is in proportion, and the air-inlet regulated up to the point of smoking, complete combustion and maximum efficacy being thus obtained. A constant surface of oil is exposed by means of horizontal, trough-like fire-bars placed one above another, on which the fuel is maintained at a constant level by means of supply and overflow. At a distance of about 1 foot from the fire-bars, full crucibles (67 lbs.) of wrought iron are melted at the rate of about 11 meltings in 12 hours, the last meltings taking only 50 minutes. The crucibles are generally used 6 or 7 times.

The wrought iron is heated just to melting, but no more; and then, as soon as the metal is molten, a small quantity of aluminium is added, from 0·05 to 0·1 per cent., producing a sudden lowering of the melting point, and thereby obtaining a superheating of 300° to 500°, enabling the metal to be handled in a practical way and poured into castings. The aluminium is added in the form of an alloy with iron containing some carbon and silicon. This is, however, no objection, on account of the very small quantity of material to be used. Messrs. Nordenfelt and Oestberg deferred taking out a patent for this addition of aluminium until they had time to go through the most exhaustive and elaborate experiments with every conceivable metal, metalloid, and alloy. And their experience is, that nothing else answers the purpose. If added in sufficient quantity, other admixtures always have some injurious effect. Carbon alone can with advantage be used in an analogous way.

One of several valuable arrangements patented for accelerating the pouring the author regards as a very important part of the inventions under his control. This is a casting-ladle provided with a cover and with means for producing a flame of high temperature within the ladle. The production of the flame is quite independent of the tipping of the ladle or the opening of the cover. By making the lining of the ladle so thick that loss of heat through radiation need not be taken into account, heating the ladle to the same temperature as the metal, and, after the metal is run in, maintaining a flame of about the same temperature, the metal may be kept in a proper state for pouring any length of time that may be required. By keeping the flame slightly reducing, the surface of the metal is protected from oxidation. The flame has its outlet over the pouring-lip, and thus protects even the jet of metal when pouring.

The castings do not require any annealing; they are ready when taken out of the mould. Their tensile strength is generally 20 to 50 per cent. greater than that of the raw material.

III.—*THE OPEN HEARTH PROCESS.*

Charges for the Open-Hearth Process.—For hard steel, Asbeck & Co. charge 15 per cent. of Bessemer pig iron, 30 per cent. of soft scrap, and 50 per cent. of steel scrap, with 3 per cent. of spiegeleisen, and 2 per cent. of ferro-manganese containing 70 per cent. of manganese.*

At Witten, for cannon steel with 0·3 carbon, and a tensile strength of 55 kilogrammes per square millimetre, the charge is 11,000 kilogrammes of scrap, with 2000 kilogrammes of pig iron and about 300 kilogrammes of ore.

---

* *Zeitschrift des Oberschlesischen Berg- und Hüttenmännischen Vereins;* through *Dingler's Polytechnisches Journal*, vol. cclix., p. 54.

At Seraing the charge is 1000 kilogrammes of pig iron and 14,000 kilogrammes of scrap; whilst at the Dillingen works the charge is 20 per cent. of pig iron and 80 per cent. of scrap; and in order to assist the decarburisation, Spanish ores from Somorrostro are added. In the former works the addition of ore is avoided, so as to preserve the furnace lining. From the Dillingen charge a steel is produced with 0·58 to 0·78 per cent. of carbon, not more than 1·0 per cent. of manganese, and less than 0·1 per cent. of phosphorus. This steel is employed for the manufacture of compound armour plates.

The Dortmund Union adds to soft scrap about 20 per cent., and to rail-ends only 9 to 10 per cent. of pig iron.

At Annen, for casting railway waggon wheels, 75 cast iron scrap (open-hearth) and 19 basic Bessemer scrap, with 0·1 per cent. of carbon, is charged with 3 of pig iron and 3 spiegeleisen. To the completed bath 40 kilogrammes of ferro-silicon are added, and then 50 kilogrammes of ferro-manganese.

At Bochum the charges average 23·53 pig iron, 71·73 scrap, and 4·74 ferro-manganese. For tyre metal, at the Phœnix Works, the charge is 500 kilogrammes of English hæmatite iron, 1000 kilogrammes of Bessemer iron, 2000 kilogrammes of scrap, usually 4000 kilogrammes of rail-ends, 1500 kilogrammes fine sheet shearings, 1000 kilogrammes scrap castings, and 500 kilogrammes of spiegeleisen; at Oberhausen, 1000 kilogrammes of pig iron, and 8500 kilogrammes of scrap.

Open-Hearth Process in Sweden.—Using coal as fuel it was found that the metal on being fused down in the open-hearth under the direct action of the flame and products of combustion, took up sulphur, the quantity so absorbed rising to as much as 0·3 per cent. of the finished metal, and making the metal very red-short. The addition of 0·5 to 0·75 per cent. of manganese was found to neutralise the action of the sulphur, and to destroy the red-shortness.*

Various additions were made to the bath with a view to prevent the sulphur being taken up, but without success. Lime was then added in the generator in the proportion of 3 kilogrammes of crushed limestone to every charge of 43 kilogrammes of coal, and this had the desired effect, sulphur no longer being taken up by the fused metal in the hearth.

At the works at Domnarfoet a portion of the scrap used in the open-hearths was successfully replaced by ore, scrap alone having been previously employed there.

---

* *Jern-kontorets Annaler*, vol. xl. p. 377.

The Modified Siemens Furnace.—F. W. Lürmann[*] criticises severely the claims and statements of Mr. F. Siemens relating to his method of heating reverberatory furnaces without direct contact with the flame. He points out that if such high temperatures are reached as is stated by Steinmann in his reports on the process, pure silica, the material stated by Mr. Siemens to be the best for the construction of such furnaces, must, if the temperature experiments of Becquerel, Violle, v. d. Weyde, and others, are at all accurate, be readily fused; and no furnace constructed of it could exist under such conditions.

IV.—*THE BESSEMER PROCESS.*

Rapid Bessemer Work.—Mr. E. C. Potter,[†] manager of the North Chicago Rolling Mill Company, publishes the following record of the work done by the Company's plant on April 26, 1886:—

Blast Furnace Department.

	Tons.
No. 5 furnace, direct metal	214
No. 6 ,, ,,	185
No. 7 ,, ,,	241
No. 8 ,, ,,	216
Total direct metal	856
Cupola metal	226
Total metal	1082

Bessemer Department.

	Tons.
First turn, 8 hours, 40 heats,	385
Second turn, 8 hours, 32 heats	310
Third turn, 8 hours, 31 heats	295
Day turn, 12 hours, 59 heats	570
Night turn, 12 hours, 44 heats	421
Total 24 hours, 103 heats	991

Rail Mill Department.

	Tons.
Day turn, 12 hours, 1803 rails, 60 lbs. per yard	479
Night turn, 12 hours, 1443 rails, 60 lbs. per yard	380
Total 24 hours, 3246 rails	859

---

[*] *Stahl und Eisen*, vol. vi. pp. 252–257.

[†] *Iron Age*, vol. xxxvii., No. 18.

The pig iron used is rich in manganese and silicon, and no final additions are made for hard steel; for the softest varieties some ferromanganese is employed. The steel produced is exceptionally pure.

Modified Form of the Bessemer Converter.—The *Iron Age*[*] gives a sketch of a modified form of Bessemer converter proposed by C. A. Caspersson of the Forsbacka Steelworks, Sweden. The sketch represents one of the two 3-ton converters in work at the Hofors Works, Sweden. The metal is tapped direct from the converter by means of a ladle attached to its mouth, and is run into the mould through a sieve. It is stated that this has a beneficial effect when casting, as less air is drawn in than when the metal is poured in a single stream, and no spluttering takes place in the mould. This effects a saving in moulds and a sounder ingot; all blowholes that may be present being situated in the centre. For hot metal thin sieves with small holes are employed, and thicker sieves with a few large holes for colder metal. For the softest steels the sieve can rarely be used, but for the harder varieties its use is stated to have given very good results.

A "hard" blow is made in from 4 to 7 minutes, and the blower has to judge from the sample ladled out from the tilted converter whether a further blow is required or not.

Spectroscope for the Bessemer Process.—The spectroscopic optometer, described by C. V. Zenger,[†] is available for the study of Bessemer converter flames, and for the analysis of the gases emanating from it. With ordinary optometers, when the aperture is too large, the images are indistinct; when too narrow, they are interfered with by diffraction. The author has therefore made use of a lens of calc-spar, cut perpendicularly to the optic axis, that is, in such a way that the optic axis of the lens coincides with the principal crystallographic axis of the spar. Two positions are thus formed in which the apertures appear single and distinct; one for the ordinary, the other for the extraordinary ray. The lens having two foci, the lengths of which are almost as 1·65 : 1·48, that is 0·165 and 0·148 metre for the extraordinary and ordinary rays, it is easy to calculate, by the ordinary method, two values of the visual distance, and if the results disagree, the error made during the experiment may be immediately seen.

---

[*] Vol. xxxvii. No. 12.

[†] *Comptes rendus de l'académie des sciences*, vol. ci. pp. 1003–1005.

Considerable errors are frequently found; for aged persons these amount to 0·01 to 0·02 metre, and more. The author finds that the accord is good, when the aperture is lighted by mono-chromatic light; and he has therefore added the spectroscope to the optometer. A mirror in which the light is reflected enables the observer to turn his back to the flame. By placing near the mirror at visual distance a micrometer on a thin plate of gypsum or mica, the distance of the most important luminous rays may be measured with precision, by taking as the starting-point the division corresponding to the double ray of sodium D_1D_2. The progress of the Bessemer process may be thus followed without fatigue to the eye, and the characteristic rays of carbon, silicon, and manganese observed.

A Machine for Ramming Plug-Bottoms and Bricks.—Mr. T. V. Hughes and Mr. F. W. Harbord * have recently patented a machine for ramming plug-bottoms and bricks for Bessemer converters, to supersede the tedious method of hand-ramming now universally employed. The machine consists of a peculiarly designed hydraulic press and table, and upon the latter stands a receptacle containing a number of vertical iron rods that can be withdrawn when the plug is finished, and thus leave passages for the blast to pass through. Into the receptacle the basic and admixed binding materials are thrown. The machine is especially adapted to the basic process, where burnt dolomite mixed with tar is used for the linings, and arrangements are made to heat the surface pressure plate, in order to prevent the tar from sticking to it, and to make it, so far as the advantages are concerned, identical with the hand-ramming process. The machine is so arranged that the material may either be subjected to a steadily increasing pressure or to a series of impacts. In the basic process a large number of bricks are used for lining the converters, and the machine is designed to make these also. The change can be effected in a few minutes by simply replacing the bottom ramming plate by a "brick plate," by means of which about ten bricks can be pressed at one operation. By the present method of hand-ramming in basic works, four to five men and a boy make two plugs during one shift, at a cost varying from 8s. to 12s. per plug, and it is estimated that with the machine one man and a boy will be able to make at least six or seven during the same time, which will reduce the cost to about 1s. for each plug. In acid Bessemer works, where ganister is used as a lining, the cost of ramming plugs by hand is less, because a large portion of the "bottom" is filled up with previously prepared fireclay tuyeres, so that the amount of labour is comparatively small, and the saving in actual labour by the use of the machine would only be about 2s. per plug. By its use, however, the fireclay tuyeres would be dispensed with, and as about fifteen of these are usually required, at a cost of 1s. a-piece, the saving would be greater than in the case of basic "bottoms" or "plugs." It must not be forgotten that tar or a similar binding material would then have to be mixed with the ganister, and about 4 to 5 gallons, at 3d. or 4d. per gallon, would be required for each plug; but taking this into account, the saving by the machine appears still considerable.

---

* *Colliery Guardian*, vol. li. p. 748.

A Modified Form of the Bessemer Process.—Professor F. Kupelwieser * states that in Luxemburg it is stipulated that the pig iron intended for use in the basic Bessemer process shall have as nearly as possible the following percentage composition:—

	Per Cent.
Manganese	1·5
Phosphorus	1·5 to 2·0
Silicon	0·8 to 1·2

The last number in the case of silicon being the highest limit allowed, though pig irons containing under 1 per cent. of silicon are considered most favourable. The ordinary Luxemburg brown hæmatite pig iron contains, however, as a rule:—

	Per Cent.
Manganese	0·2 to 0·4
Phosphorus	1·5 to 2·0
Silicon	1·5 to 2·0

In order to obtain pig iron of the right composition for the basic process, experiments have been made at the Hollerich Works with a view to treating the ordinary variety of pig iron in such a manner as, by eliminating silicon, to render it suitable for use in the converter. Two acid-lined Walrand converters were used, and the pig iron partially blown in one of them. The converters held about a ton of pig, and the tuyere nozzles were 20 centimetres above the converter bottom. The pressure of the blast varied according to the composition of the pig treated, from 30 to 35 centimetres of mercury, but rarely reached 50 centimetres. After the converter had been heated up, the pig iron was charged in and blown for about ten minutes in the acid-lined converter, and was then run into the basic converter and the blow completed in the ordinary manner. With a pair of converters of this kind it is possible to make about 30 blows in 24 hours, and the daily production of a fair-sized blast furnace could consequently be treated.

---

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxiii. pp. 681–683.

The quality of the products obtained is exceedingly good, and the following are partial analyses of the pig iron used, and of the ingot metal produced from it:—

Pig Iron.

	I. Mottled.	II. Grey.
	Per Cent.	Per Cent.
Carbon	3·467	3·504
Silicon	0·915	1·563
Sulphur	0·099	0·083
Phosphorus	1·994	1·514
Manganese	0·354	0·366

Ingot Metal.

	I.	II.
	Per Cent.	Per Cent.
Carbon	0·218	0·158
Silicon	0·050	0·065
Sulphur	0·063	0·058
Phosphorus	0·014	0·007
Manganese	0·248	0·269

The results of the physical tests were very favourable.

Bessemerising with Small Converters at Avesta.—F. Fischer * states that the pig iron varies from deep grey to slightly mottled, flows sluggishly, and is not hot, and that it is run direct from the furnace into the converter, the distance between the two being about 3 yards. There are two converters; and the charge varies from 5·5 to 6·4 metric cwt. for the smaller and from 8·5 to 9·35 cwt. for the larger converter. The first blow witnessed by the author was in a converter the lining of which had already sustained eight blows. In the beginning the pressure in the blast-pipe was 10 lbs., and this was kept up during the first period, lasting three minutes. When the first indications of a carbonic oxide flame appeared the pressure was lowered to 7 lbs. This was kept up for one minute and a half, until only a carbonic oxide flame was visible, and then the pressure was again raised to 10 lbs. The decarbonising period lasted three minutes. After the flame had entirely withdrawn into the neck of the converter the metal was overblown twenty seconds. Then 1 per cent. of ferro-manganese was added and the bath thoroughly stirred with a pole. The steel was allowed to stand in the converter until it had become quite quiet and no flames made their appearance. The metal was then cast. The second charge was blown on a new cold bottom at the beginning of the blow, the pressure of the blast being 12 lbs. The first period lasted about six minutes, against three minutes in the first blow witnessed. When the carbonic oxide flame first made its appearance the pressure was reduced to 6·5 lbs., at which point it was continued for two minutes ten seconds. Afterwards the pressure was again carried up to 12 lbs., and kept there for 3·5 minutes. This was followed by a period of rest and by the cast. The ingots were stripped as soon as possible, and were put into soaking-pits previous to rolling. The author gives the following as the results of a series of mechanical tests:—

---

* *Oesterreichische Zeitschrift für Berg-und Hüttenwesen*, vol. xxxiv. p. 244

No.	Contraction of Area.	Elongation.	Tensile Strength.
	Per cent.	Per cent.	Tons per Sq. Inch.
1.	69·1	23·5	22·7
2.	75·8	23·75	23·7
3.	62·3	20·0	24·1
4.	54·5	10·5	24·8
5.	52·4	21·0	22·9
6.	72·3	25·75	23·7
7.	40·4	15·25	22·7
8.	38·9	16·5	22·2
9.	68·2	21·5	23·6
10.	65·8	23·5	23·7
11.	61·7	32·0	22·7
12.	63·9	32·0	22·7
13.	66·4	36·5	21·9
14.	65·7	29·0	24·7

All these tests were made at right angles to the direction of rolling. Analysis yielded the following comparative results between Avesta and open-hearth metal:—

	Avesta Steel Plate.	Open-Hearth Steel Plate.
	Per cent.	Per cent.
Carbon	0·14	0·17
Silicon	0·014	0·023
Manganese	0·30	0·33
Phosphorus	0·062	0·041
Cinder	0·09	0·04

The Clapp-Griffiths Process.—Mr. J. P. Witherow * states that the difficulties experienced during the experimental period of the development of this process are now avoided by improved cranes and other appliances. The introduction of movable bottoms has proved a complete success, natural gas providing the means for the thorough drying absolutely necessary. It is not at all uncommon for the bottoms to last for sixty heats without being touched. On October 12, 1885, the works of Oliver Brothers & Phillips were started on double turn. The following is the record to October 24:—

October	Day.	Night.	October	Day.	Night.
	Blows.	Blows.		Blows.	Blows.
12	28	36	19	35	28
13	37	38	20	35	40
14	37	38	21	42	38
15	37	33	22	39	39
16	31	30	23	35	32
17	31	...	24	22	...
	201	175		208	177
Total . .	376		Total . .	385	

Previous to October 12 the regular charge blown was 4000 lbs., but on that day it was increased to 4500 lbs., and has since remained at the latter weight. The production can thus be easily held at 150 to 175 tons daily. During the first of the above weeks but 8 bottoms were used. The following week 9 bottoms were used, making an average of over 44 blows to the bottom.

The paper is accompanied by drawings of the most improved form of converter.

The Grading of Bessemer and Open-Hearth Steel at Reschitza.†—The Bessemer and open-hearth steel at the works of the Austro-Hungarian State Railway Company at Reschitza, in Southern Hungary, is made from charcoal pig iron direct from the blast furnace, and without any subsequent addition of pig iron. The steel is graded, according to the scale of hardness proposed by Tunner, in seven numbers. Besides this numbering with whole numbers, from the hardest steel to the softest iron, there is distinguished with each number a harder and softer variety, the numbers being expressed in thirds. For example, in addition to No. 4 of the scale, there are No. 4 hard ($=3\frac{2}{3}$) and No. 4 soft ($=4\frac{1}{3}$). This numbering or grading gives a number of members quite sufficient for all practical purposes. The hardest unweldable numbers, 1 and 2, are only made for special orders.

---

* *Transactions of the American Institute of Mining Engineers*, vol. xiv. pp. 919-941.

† *Berg- und Hüttenmännische Zeitung*, vol. xliv. pp. 462-464.

The grading is effected by observing the behaviour on breaking, the appearance of the fracture of a test ingot, and the behaviour of the same on heating, forging, rolling, welding, hardening, breaking, and from the appearance of the fracture of the forged and hardened test-piece. Tensile tests are made, and the percentage of carbon determined by Eggertz's method. And, occasionally, the grading is checked by chemical analyses.

The following table shows the characters of the Reschitza Bessemer and open-hearth steel according to tests made at the Royal and Imperial Polytechnic Institute at Vienna:—

Hardness No. according to Mechanical Test.	Carbon per Cent.	Sp. Gr.	Modulus of Elasticity, in kg. per sq. mm.	Tensile Strength at the Limit of Elasticity, in kg. per sq. mm.	Tensile Strength at the Limit of Cohesion, in kg. per sq. mm.	Greatest Elastic Elongation, per Unit Length.	Greatest Total Elongation, per Unit Length.
I.	1·50	...	...	...	...	...	...
II.	1·25	...	...	...	...	...	...
III.	1·00	7·826	17,768	17·81	62·92	0·00100	0·055
IV.	0·75	7·840	17,434	16·79	56·66	0·00096	0·142
V.	0·50	7·853	19,478	21·57	50·06	0·00110	0·158
VI.	0·28	7·865	17,525	18·86	48·03	0·00109	0·153
VII.	0·12	7·879	18,371	22·05	44·96	0·00120	0·148

I. and II. Very hard steel, forges well, does not weld, and is only used for exceptional purposes. III. Hard steel, forges very well; is employed for chisels, borers, stamps, cutting tools, anvils, files, and springs. IV. Moderately hard steel, forges excellently, and welds more easily than weldable cast-steel; used for tyres, machine parts, files, swords, and knife-blades. V. Soft steel, forges and welds excellently; used for tyres, rails, plates, angles, machine parts, springs, and bolts. VI. Hard or fine-grained iron; used for rails, angles, boiler-plates, machine parts, and for structural purposes. VII. Soft iron; used for soft plates and wire.

Grinding Basic Bessemer Slag.—According to Horn,* the principal difficulty in grinding basic Bessemer slag is the presence of metallic iron. It is best to crush the slag roughly in roller mills, and sort it afterwards by means of inclined sieves (Nagel & Kaemp's patent). By this means the iron can be removed. The comminution may then be effected in horizontal mills.

---

* *Berg- und Hüttenmännische Zeitung*, vol. xlv. pp. 40–42.

The Utilisation of Basic Slag.—Baron von Maltzau[*] remarks that, in order that the material should be a good manure, the iron, the ferrous oxide, and the iron and calcium sulphides it contains must be eliminated. The large quantity of lime present is also of great importance as regards the further treatment of the slag, and the author draws attention to the use of sulphurous anhydride for the purpose of converting the lime into sulphate. The gases from calciners where sulphides are treated, rapidly attack the powdered basic slag, converting the lime into sulphate, oxidising any metallic iron that may be present, as well as ferrous and manganous oxides and the sulphides. On further treatment of the slag by acids the whole of the acid is saved which would otherwise have been lost in the neutralisation of the lime, and very little iron passes into the solution. The process is criticised unfavourably by L. Blum;[†] and in a further article Baron von Maltzan replies to this criticism.[‡] M. A. von Reis[§] has observed that the phosphoric acid of the basic slag is easily dissolved by water containing carbonic anhydride.

Experiments to test the value of basic iron cinder for manure have been made by Professor Wrightson and Dr. Munro.[||] The experiments were conducted in duplicate on a chalk soil at Downton, Wilts, and on a clay soil at Ferryhill, Durham, and the details have been published in a report furnished to the North-Eastern Steel Company. An analysis of the basic cinder used gave the following results:—

Phosphoric Anhydride.	Lime.	Magnesia.	Silica.	Alumina.	Ferrous Oxide.
14·32	41·54	6·13	7·4	2·6	8·66

Applied to turnips, ½ ton of the new ground cinder per acre doubled the produce at Downton and quadrupled it at Ferryhill, as compared with the yield of adjoining unmanured plots; while 4 cwt. per acre gave an average increase on two plots of 47 cwt. of roots per acre on the chalk soil, and of 112 cwt. on the clay. On the chalk soil 4 cwt. per acre of basic cinder gave lower results than an equal weight of mineral superphosphate; but on the clay soil it proved equal or superior, and on both soils it produced more than did an equal weight of ground coprolites. Experiments with precipitated phosphate of lime from basic cinder were also very favourable to the new manure.

---

[*] *Chemiker Zeitung*, vol. x. pp. 83–103.
[†] *Ibid.*, vol. x. p. 339.
[‡] *Ibid.*, vol. x. p. 432.
[§] *Ibid.*, vol. x. p. 531.
[||] *Iron and Coal Trades Review*, vol. xxxi. p. 570.

FURTHER TREATMENT OF IRON AND STEEL.

Wire Drawing without Pickling in Acids.—Dr. H. Wedding * shows that the production of wire in Germany has increased enormously of late years, the quantity produced in 1883 being nearly forty times as much as was produced in 1850.

With regard to the question as to what improvements can be made by wire manufacturers so as to lower the cost of production, the author shows that the annealing and dipping play an important part in the cost, besides which sulphuric acid being chiefly employed in this last operation, and the by-product so produced being almost valueless, the waste liquor is usually allowed to flow away from the works into running streams, thus interfering to a considerable extent with other works in the neighbourhood. Neutralisation of this waste liquor by lime, as has occasionally been tried, is not possible, as a large excess of lime and heat would be required in order to produce a successful result, and a muddy deposit would be formed which would be almost more injurious than the basic iron salts or the sulphuric acid itself.

In practice there are two conditions when wires require to be attacked with acids; in the first place, the wire leaves the rolling-mill at a bright red heat; being in contact with the air it is oxidised on the surface, and this scale has to be removed before the wire can be drawn. Secondly, owing to changes in the molecular position, the wire during drawing becomes hard on the surface, and there is, in consequence, considerable internal tension, and this requiring careful annealing a further acid dip is necessary. In practice this operation takes place five times, viz., at a diameter of 3·8 millimetres, again at 2·2–2·0 millimetres, at 1·6 millimetre, at 1·1, and at 1·0 to 0·7 millimetre. The consumption of acid amounts to at least 25 kilogrammes per ton of wire, 6·5 kilogrammes of this being used in drawing, and the remainder during the preliminary rolling. The rolled wire is freed from scale by a mixture of 1 to 1·2 litre of sulphuric acid of 60° B. and 100 litres of water. The scale is only partially dissolved, but is loosened from the wire by the acid getting inside the scale and forming bubbles of hydrogen. The wire, after being dipped, is washed with dilute milk of lime, and then dried on a charcoal fire. Acid of 50° B. heated by a steam coil is also sometimes employed.

---

* *Stahl und Eisen*, vol. vi. pp. 14–24.

The author shows that it is impossible for the sulphuric acid to be replaced in practice by any other solvent, and that it is therefore necessary to look to the mechanical side of the question for the removal of the scale. The first to give attention to this subject was Betz of St. Ingbert, who patented in Prussia a machine for the purpose in 1873, and in the United Kingdom in 1877. A series of rollers are used, placed at right angles to each other, and the wire is passed between them. It has, however, only come into partial use, partly on account of its cost, and in part to its not being adapted for fine wire.

Various improvements on this plant are noticed by the author, who then mentions his own experiments on the subject. He has found that if a wire be strained at the moment when the elastic limit is reached, nearly all the larger portions of the scale fly off, and even the thin scale is to a great extent eliminated by vibrating the wire when under tension. He proposes that the wire as it comes through the rolling-mill should be treated in this manner, first cooling it by hot water.

Passing to the consideration of the drawn wire, the author discusses the various methods that had been proposed for freeing it from scale and preventing its oxidation both after drawing and on re-heating, and he then describes some experiments of his own, in which he considered the drawing of fine wire from the four following points of view:—

1. Whether it is not possible to draw a wire coated with scale without first removing the scale, although the thickness of this latter might only be 0·05 millimetre.

His experiments showed that it was perfectly possible, for not only was the power required to draw the wire very high, but the drawing proceeded in jerks, and the hole through which the wire was drawn widened very rapidly. On annealing and dipping the wire, the power required to draw it was found to be only two-thirds of that previously employed.

2. As to the action of various salts and caustic soda during drawing, and the effect of covering the wire with a thin metallic layer.

The wire to be drawn was passed through concentrated solutions of common salt, magnesium sulphate, and a number of other salts; but the results showed that the power required to draw the wire after passing through these solutions was even greater than that required in the case of the unannealed wire. Coating the wire with a thin layer of copper by passing it through a solution of cupric sulphate was also tried, but the result was unsatisfactory. Caustic soda was also found useless as a lubricator.

3. As to the temperature which is required on annealing the wire.

The author, considering that the temperature employed in practice is far too high, and that, consequently, both fuel and time are lost unnecessarily, has instituted some experiments, using for the purpose of annealing, baths of substances having melting-points varying from 150° C. to nearly 800° C. These substances were (1) an impure paraffin which was employed at its melting-point, 150° C., and at its inflaming point, 245° C.; (2) tin, with a melting-point of 235° C.; (3) lead, 334° C.; (4) zinc, 433° C.; and (5) common salt, fusing at 776° C.

In each case the wire passing through the bath was heated to the temperature of the bath, and was then passed through the draw-plate either at as nearly this temperature as was possible, or it was first allowed to partially cool by passing it for a distance of two metres through air.

The power required to draw the unannealed 2-millimetre wire was originally 105 kilogrammes, after annealing and dipping 67, and, after passing through under both the conditions above stated, the paraffin bath at its melting-point, the power required for drawing was reduced to 80 kilogrammes, and to 60 when the paraffin bath was heated to 245°. In the case of the tin bath, the wire drew with 52 kilogrammes when hot, and with 80 when cold. With the lead bath 60 kilogrammes were required for the hot wire, and 85 for the cold; with the zinc bath 130 kilogrammes when hot, and 150 when cold, were required. Using common salt as the bath, 70 kilogrammes were needed to draw the wire when hot, and 90 after having been cooled in the manner described above.

The draw-holes were considerably enlarged by the passage of the wire after using both salt and zinc, and these can evidently be of no use for annealing purposes in practice.

On comparing the drawing qualities of the paraffin, tin, and lead baths, it was found that the wire annealed in the tin bath would not stand being drawn twice; the wire annealed in paraffin broke on the fourth draw; but in the case of the wire annealed in lead, the drawing operation could be completed.

The actual and stated diameters of the wires after passing through the different draw-holes were also determined, as was the force required to draw the wire through each of the several holes in the case of the wire annealed in the lead bath. The wire finally obtained had a diameter of 0·99 millimetre, and was of perfectly good quality. The author is therefore of opinion that the temperature of fused lead, 334° C., is quite sufficient to destroy the tension produced in the wire during the drawing, and although in the experiments the wire was passed through the lead bath after each drawing, he considers that in practice it would be found sufficient to anneal the wire less frequently.

In the discussion on the paper, it was stated that the separation of the scale by mechanical means was found to be considerably dearer than when hydrochloric acid was employed. It was also stated that when attempts were made to galvanise a soft iron wire freed from scale by passing through hydrochloric acid contained in leaden tanks, it was found to galvanise badly, and to be covered with black spots. This was found to be due to the lead having passed into solution, and having been afterwards deposited on the wire.

Wire-Drawing.—W. Bädeker,* in discussing the results arrived at by Dr. Wedding* in his experiments on this subject, disputes the practical value of the lead bath suggested, remarking that Dr. Wedding's experiments, in which a short length of wire was passed through the bath at the rate of 2 metres per minute, cannot be compared with what would happen in practice where a wire some 800 or 900 metres long would pass through the bath at the rate of about 50 metres per minute. In this case he considers the method would be impracticable, and, further, he has found experimentally that the temperature of the lead bath is almost without influence on the ultimate tensile strength of the wire, while heating it to a temperature of from 700° to 800° decreased its tensile strength about 60 per cent.

Steel Sleepers for Permanent Way.—According to J. W. Post,† it is generally agreed that:—The average life of good steel sleepers is considerably longer than that of the best wooden ones. The width of gauge is better maintained with steel sleepers. The cost of maintenance of permanent way on steel sleepers remains almost constant after the second year, but on wood sleepers increases constantly with age, so that the average cost of the latter is greater. There are systems of fastenings on steel sleepers which are safer and more easily maintained than those for wooden sleepers. A good steel sleeper should not cost more than from 125 to 150 per cent. of the cost of a wooden sleeper. The old material value of a steel sleeper is greater than that of a wooden one.

---

* *Stahl und Eisen*, vol. vi. pp. 181 and 276.

† *Schweizerische Bauzeitung*, vol. vi. pp. 37–43; *Minutes of Proceedings of the Institution of Civil Engineers*, vol. lxxxiii. pp. 496–500.

After a series of tests of iron and steel sleepers of various designs, the Netherlands State Railway decided in favour of mild steel sleepers, 8·5 feet long, 9·25 inches wide, 2·52 inches deep for the greater part of the rail, but increased to 2·92 inches under the rail, and 3·23 inches at about 4 inches outside the rail, so as to give the inclination of 1 in 20 for the cant of the flat-bottomed rail, which rests directly on the sleeper. The weight is 104·7 lbs., while a sleeper of the same strength with a uniform instead of a varying cross section would weigh 15 per cent. more. The last steel sleepers ordered (July 1885) cost at the works, including a two years' guarantee, not quite six francs each, or almost the same as an oak sleeper.

Annual Cost of Wooden and Iron Sleepers.—In connection with the life of iron sleepers, G. Meyer [*] notes that they suffer less from atmospheric agencies than wooden ones. Iron sleepers laid in 1864 on the Brunswick railway were found in 1882 to be but slightly affected by rust. With the heavier sections now used, the breaking of a sleeper is so unusual as not sensibly to affect the annual charge. The life has been estimated at from 30 to 50 years, while opponents of the system place it at not more than that of the best wooden sleepers, or 20 years. This estimate is, however, disproved by the more than 20 years' experience of the longitudinal sleepers on the Brunswick railway. Iron cross sleepers of 110 lbs. weight, costing 7s. 2d. each, only require to last 25 years in order not to involve an annual charge of more than 4·8 pence, the average for wooden sleepers on German railways.

The Relative Value of American and Krupp Steel Tyres.—In reply to an inquiry by Mr. Leach of the Nashua Steelworks, United States, the master of machinery of the Central Pacific Railway states that he has used the American tyre ever since it has been manufactured, and that he considers it far superior to Krupp's or any other imported tyre.[†]

---

[*] *Organ für die Fortschritte des Eisenbahnwesens*, 1885, p. 194; *Minutes of Proceedings of the Institution of Civil Engineers*, vol. lxxxiii. pp. 494–496.

[†] *Iron Age*, vol. xxxvi. No. 23.

Mr. Leach states that the general average of all American tyres on the Wabash, St. Louis, and Pacific Railway from Jan. 1, 1880, to Jan. 1, 1882, was for $\frac{1}{16}$ inch wear 9704 miles, and of all Krupp's tyres 7516 miles.

Mr. Griggs of the Providence and Western Railway gives the following statement showing the wear of driving tyres in freight service, no driver brakes being used. All engines were precisely similar, having 18 by 26 inch cylinders, and a total weight of 82,000 lbs. The tyres were originally 3 inches thick.

	Standard.	Krupp.	Krupp.
Present thickness . . . . inch	$1\frac{5}{8}$	$1\frac{1}{2}$	$1\frac{13}{16}$
Total number of miles run	243,007	168,772	181,105
Number of times turned	6	5	3
Average mileage each turning	40,501	33,754	60,368
Average thickness taken off at each turning . inch	0,229	0,300	0,396
Greatest mileage between turnings	56,702	51,127	62,835

PHYSICAL AND MECHANICAL PROPERTIES OF IRON AND STEEL.

The Electrical and Magnetic Properties of Wrought Iron, Steel, and Cast Iron in Different States of Hardness.—Carl Barus and Vincent Strouhal * give in complete form the results of five years of research on the properties of the iron carbides. The experiments form an extensive series, and the results deduced from them are of great interest.

The remarks in the memoir refer almost exclusively to the species of hardness known as temper. The first three chapters of the book give the results of auxiliary experiments investigating the physics of the operation of tempering. The general deduction is, that if one and the same steel rod pass from an initial hard to a final soft state, any intermediate degree of hardness can be defined with extreme accuracy, by using as a means of discrimination either the thermo-electric power or the electrical resistance of the rod. Like the specific resistance, the galvanic temperature co-efficient of the iron carbides exhibits a phenomenal range of variation, passing from the values for wrought iron and soft steel, 0·0052 and 0·0043 respectively, to the values for hard steel and cast iron, 0·0016 and 0·0013 respectively. This co-efficient decreases continuously as resistance increases; an inferior limit of the temperature co-efficient appearing before the iron carbide reaches the superior limit of resistance. If classified with reference to the relation between resistance and temperature, the iron carbides, as a whole, form one continuous series. In the second chapter, the electrical behaviour of tempered steel is minutely analysed. Experiments show that the annealing effect of any temperature acting on glass-hard steel is found to increase gradually, at a rate diminishing continuously through infinite time—diminishing very slowly in the case of low temperatures (less than 100°), very rapidly at first, then again slowly in the case of high temperatures (greater than 200°); so that the highest and hardest of the inferior states of hardness possible at any temperature is approached asymptotically. In the case of steel, the relation between thermo-electromotive force per degree centigrade at 0°, and specific resistance at 0°, is linear throughout the whole of the range of these qualities with hardness. This law suggests the introduction of the new variable *thermo-electric hardness,* which is used as the measure of hardness throughout the work. This may be defined thus:—Assuming the law of linear variation to be true indefinitely, then the electro-motive force per degree C. at 0° of a thermo-element consisting of steel in the imaginary normal state, the specific resistance of which is zero, and steel in any given state, will be the thermo-electric hardness of the latter. In Chapter III. the attempt is made to throw new light on the laws set forth in the preceding chapter by following them into their ulterior consequences. With the aid of allied electrical properties observed in alloys of silver and in malleable cast iron, the nature of the phenomenon of hardness as presented by steel is discussed.

---

* *Bulletins of the United States Geological Survey,* vol. ii. No. 14, pp. 597–830.

Both the galvanic and the thermo-electric effects of magnetisation may be neglected in comparison with the corresponding electrical effects of tempering, the former amounting to less than 0·3 per cent. of the latter in the most unfavourable case. The absolute value of the thermo-electric effects for magnetically saturated iron is +0·035 microvolts per degree Centigrade, at zero. The thermo-electric effects of a temporary tensile strain in iron and of magnetisation are quantitatively alike. Consequently, the latter effect is to be attributed to the strain which accompanies magnetisation.

Chapter V. exhibits, with some detail, the effect of hardness on the maximum of magnetisation permanently retained by thin cylindrical steel rods of different dimensions. Chapter VI. investigates the bearing of temper on the condition of magnetic stability of steel. Whenever great retentiveness, as regards the hurtful effects of temperature, time, and shocks, is to be conveniently attained with the least sacrifice of magnetisation, magnets should be treated thus:—

1. Rods tempered glass-hard are not to be used as essential parts of magnetic instruments. 2. Having tempered a given rod in such a way as ensures uniformity of glass-hardness throughout its length, expose it for a long time, say twenty to thirty hours, to the annealing effect of steam at 100° C. The operation may be interrupted as often as desirable. The magnet will then exhibit the maximum of permanent hardness for 100° C. 3. Magnetise the rod—whether originally a magnet

or not is quite immaterial—to saturation, and then expose it again for about five hours (in case of massive magnets even larger intervals of exposure are preferable) to the annealing effect of steam. The operation may be interrupted as often as desirable. The magnet will then exhibit both the maximum of permanent magnetisation as well as the maximum of permanent hardness corresponding to 100°. Its degree of magnetic retentiveness against effects of temperature, time, and percussion, is probably the highest conveniently attainable.

Finally, in Chapter VII. the authors deduce a method for the physical definition of iron carbides. Assuming carburisation to vary continuously from 0 to 6 per cent. by weight of the whole, and in such a way that increment in total carbon is compensated by decrement in total iron, in this way a special *series* of iron carbides is generated, of which the given carbide is a particular member.

On comparing the effects of slow and sudden cooling on such a series, by means of the determination of the thermo-electric hardness, and of the specific resistance of the individual members in both states of hardness, it will be found, on plotting the curves with carbon percentages as abscissæ, and thermo-electric hardness or specific resistance as ordinates, that in both cases there is an increase of these qualities with increase of carbon. The manner of increase, however, is different. Starting with pure iron, where the curves of sudden and slow cooling are coincident, and constructing the curve of sudden cooling, we find that it is concave toward the axis of abscissæ, and on constructing the curve of slow cooling we find that it is convex. These curves will again intersect at some point near 5 or 6 per cent. carbon. If now a fresh curve be constructed, using as ordinates the difference between the logarithms of the pairs of values of thermo-electric hardness, it passes through a very sharp maximum in the region of 1·5 per cent. carbon. If instead of thermo-electric hardness specific resistance is taken, a similar maximum is found, viz., about 2 per cent. carbon. The authors propose that this maximum state be taken as defining the normal steel. It is now easy, by determining the maximum and minimum values of thermo-electric hardness of any member of the series, to classify it according to its carbon percentage, other things remaining the same.

The Influence of Silicon upon the Properties of Cast Iron.—Mr. T. Turner * has prepared "pure cast iron," that is, cast iron as free as possible from the ordinary impurities, by heating wrought iron with charcoal for five hours. The composition of the product was—

---

* *Journal of the Chemical Society*, vol. xlvii. pp. 577–586.

Total Carbon.	Graphite.	Silicon.	Manganese.	Phosphorus.	Sulphur.
1·98	0·38	0·19	0·14	0·32	0·35

The cast iron was then melted with suitable quantities of silicon pig iron containing—

Total Carbon.	Graphite.	Silicon.	Manganese.	Phosphorus.	Sulphur.
1·81	1·12	9·80	1·95	0·21	0·04

From the product test-bars about 1·1 inch in diameter and 19·7 inches long were prepared. These bars, tested by Professor Kennedy, gave the following results:—

Silicon.	Breaking Load per Square Inch.		Modulus of Elasticity.
Per cent.	Lbs.	Tons.	Lbs.
0·0	22,720	10·14	25,790,000
0·5	27,580	12·31	28,670,000
1·0	28,490	12·72	31,180,000
2·0	35,180	15·70	23,560,000
2·5	32,760	14·62	25,450,000
3·0	27,390	12·23	21,150,000
4·0	25,280	11·28	15,640,000
5·0	22,750	10·16	18,720,000
7·5	11,950	5·34	14,750,000
10·0	10,630	4·75	13,930,000

These results show that, contrary to the accepted views on the subject, a suitable addition of silicon to cast iron improves the tensile strength of the metal. Any further addition, however, beyond 2·5 per cent. causes a gradually increasing deterioration.

Each test-piece was analysed after fracture, and the results show that the actual silicon and carbon percentages are always very near to that desired, while the sulphur and phosphorus are fairly constant. The manganese increases gradually up to 1·95 per cent.

In the second part of his paper,* Mr. Turner gives an account of experiments on the relative density, hardness, working qualities, and crushing strength of the metal, and discusses the reason of the variations noticed.

The relative density was determined both in mass and in small fragments. In the first case cylinders 3 inch by 1 inch were employed, and the turnings from the cylinders were used for a second determination. In iron possessing great tenacity the density was slightly increased, but with less tenacity the density was decreased by the force exerted in turning the metal. The hardness was measured by the weight in grammes necessary to produce a scratch with a cutting diamond. The influence of silicon is shown to be quite regular, the greatest softness being produced by from 2 to 3 per cent. The working qualities are taken from the observation of a skilled workman, and agree very closely with the hardness as before determined.

---

* *Journal of the Chemical Society*, vol. xlviii. pp. 902–916.

The crushing strength tests were performed by Professor Kennedy on cylinders 3 inch by 0·75 inch. The influence is tolerably regular and of the kind previously observed, the maximum value being reached with 1 per cent. of silicon.

In the following table a summary is given of the chief results:—

Silicon per Cent.	Relative Density of Cylinders, 3 inches by 1 inch.	Relative Density of Turnings from Cylinders.	Relative Hardness.	Crushing Strength. Breaking Load per Square Inch.	
				lbs.	Tons.
0	7·560	7·719	72	168,700	75·30
0·5	7·510	7·670	52	204,800	91·42
1	7·641	7·630	42	207,300	92·54
2	7·518	7·350	22	135,600 139,000	60·53 62·05
2·5	7·422	7·388	22	172,900	77·18
3	7·258	7·279	22	128,700	57·45
4	7·183	7·218	27	106,900	47·74
5	7·167	7·170	32	103,400	46·16
7·5	7·128	7·138	42	111,000	49·55
10	6·978	6·924	57	76,380	34·10

The author draws the following conclusions:—

1. That a suitable small addition of silicon to cast iron almost entirely free from silicon is capable of producing a considerable improvement in the mechanical properties of the metal.

2. That in these experiments the maximum values are probably reached with the following amount of silicon:—

Crushing strength	**about 0·80 per cent.**
Modulus of elasticity	**,, 1·00 ,,**
Relative density (in mass)	**,, 1·00 ,,**
Tensile strength	**,, 1·80 ,,**
Softness and working qualities . .	**,, 2·50 ,,**

3. That when general strength is required, the amount of silicon should not vary much from about 1·4 per cent.; but when special softness and fluidity are desirable, about 2·5 per cent. may be added. Even in the latter case, however, any increase upon 3 per cent. must be dangerous.

These conclusions are only strictly true under the circumstances of the author's experiments, but he hopes shortly to bring forward evidence from independent investigations to support his results. He is decidedly of opinion that the production of graphitic carbon is not the only cause of these differences, but that, in addition to the indirect effect owing to the production of grey iron, the suitable addition of silicon has a direct and beneficial influence upon the mechanical properties of the metal.

In the third part of his paper* the author shows that previous results strongly support his conclusions, although opposite opinions have been generally held.

The Woolwich report, "Cast Iron Experiments, 1858," is considered in detail. This report gives the results of the analysis and mechanical tests of seventy specimens of cast iron, seven of which were of foreign origin. Only eight specimens were mentioned as being too hard to turn. Seven of these contained under 0·9 per cent. of silicon, while the eighth was rich in phosphorus and sulphur. These facts support the author's conclusion that a softening effect is produced by a suitable proportion of silicon. The six best specimens mentioned in the report contained on an average 1·393 per cent. of silicon, while the author, from his own experiments recommended about 1·4 per cent. The six specimens lowest in silicon are of intermediate quality, while the six specimens highest in silicon are of inferior quality. These results show that a suitable proportion of silicon is beneficial.

When the specimens are classified according to their proportion of phosphorus, and arranged in order of silicon present, a gradual improvement is noticed as the silicon increases until a certain point is reached, beyond which the metal deteriorates in quality. In one table, however (0·2 to 0·4 per cent. of phosphorus), no such regularity is observed. This is due to the small variations in silicon and the large alterations in the proportions of other elements present.

Selecting from each table the specimen which apparently contained the most suitable proportion of silicon, the following result is obtained:—

	Silicon per cent.
1. English irons in the appendix	1·03
2. Containing 0·4 to 0·6 per cent. of phosphorus . .	1·21
3. Foreign irons in the appendix	1·33
4. Average of six best specimens	1·39
5. Containing 1·0 per cent. of phosphorus . . .	1·41
6. Containing over 1·0 per cent. of phosphorus . .	1·57
7. Containing under 0·2 per cent. of phosphorus . .	1·88

---

* *Journal of the Chemical Society*, vol. xlix. pp. 130–149.

The Condition of Silicon in Cast Iron.—Messrs. A. E. Jordan and T. Turner[*] have endeavoured to ascertain whether silicon can be separated from cast iron. They refer to the work of Wöhler, Richter, and others, who believed they had obtained silicon crystals, and also to the experiments of Snelus,[†] Morton, and Tilden, who were unable to separate silicon from cast iron in this form.

Several irons, including a specimen with 9·8 per cent. of silicon, were submitted to a magnetic examination. It was, however, not found possible to separate silicon in this manner.

The residue left after prolonged boiling with dilute hydrochloric acid was then studied. After drying, the graphite was burned off in a muffle, and the remainder examined for silicon. In no instance was silicon found; but in the case of a pig iron with 10·3 per cent. of silicon, black scales of iron silicide were obtained. These scales closely resemble in properties the so-called graphitic silicon of Richter. In the residue, before roasting, the authors found a substance resembling Wöhler's "leucone," the "silicon formanhydride" of Friedel and Ladenburg.

Lastly, graphitic matter from iron was examined. For the specimens examined the authors are indebted to Dr. Percy. The first was graphite from Dowlais, a specimen examined by Dr. Percy.[‡] It was found to be nearly pure carbon, and to be almost entirely free from silicon in any form. A specimen of kish, from the Clarence Works, Middlesbrough, was also examined, but in this case, too, no crystallised silicon was found.

The authors conclude that silicon is present in cast iron in the form of silicide, which is dissolved when fluid, in the excess of iron present.

Liquation Phenomena in Spiegeleisen.—B. Platz[§] has observed the separation of a crystalline body during the solidification of spiegeleisen. Analyses of different specimens of spiegeleisen from which such separation occurred, as well as of the liquated product, gave the following results:—

---

[*] *Journal of the Chemical Society*, vol. xlix. pp. 215–222.

[†] See *Journal of the Iron and Steel Institute*, 1870, p. 28.

[‡] "Metallurgy, Iron and Steel," 1864, p. 145.

[§] *Stahl und Eisen*, vol. vi. p. 244.

	Spiegeleisen.	Liquated Product.
	Per cent.	Per cent.
Manganese	6·120	6·570
Carbon	4·391	4·808
Phosphorus	0·525	0·171
Silicon	0·395	0·260
Manganese	6·008	6·970
Carbon	4·376	4·768
Phosphorus	0·591	0·378
Silicon	0·521	0·229
Manganese	5·872	6·380
Carbon	4·283	4·627
Phosphorus	0·561	0·272
Silicon	0·313	0·101

It will be observed that, in each of the three cases, there is less phosphorus and silicon, and more manganese and carbon in the product of liquation than in the original spiegeleisen.

On dissolving the liquated substance in hydrochloric acid, it was found that, while spiegeleisen leaves a brown-coloured residue containing carbon, silicon, and iron, the liquation product left on solution silicon only, without admixture of iron or carbon, the whole of the carbon being evolved in the form of hydrocarbons.

The Crystallisation of Wrought Iron.—In a paper read at the Boston meeting of the American Society of Mechanical Engineers, Mr. Hill described a specimen of wrought iron in which crystallisation had apparently taken place under the influence of the continued repetition of violent shocks. The specimen was from the lower end of a hammer bar of a 2000-lb. Seller's steam-hammer.

The Contraction of Iron on Sudden Cooling.—If a bar of wrought iron or steel is suddenly cooled from a bright red-heat, the contraction which then occurs is considerably greater than the expansion previously caused by heating the bar, so that its final length is considerably less than its initial length. This phenomenon has been investigated by Mr. T. Wrightson,* who ascribes it to some molecular change caused by sudden cooling. Mr. H. M. Howe,† however, is of opinion that it is due to a very simple and purely mechanical action.

Let the cooling be considered as divided into two periods, in the first of which the exterior of the bar becomes almost completely cooled, and hence tends to contract almost to its initial dimensions, while the still hot and plastic interior contracts but little; in the second period the already cool skin remains nearly constant in temperature, and hence tends to contract but little, while the interior cools from a comparatively high temperature to the ordinary temperature, and hence undergoes great contraction. The excess of the contraction of the skin over that of the interior during the first period tends to make the bar bulge in the middle of its length. In the second period, the tendency of the interior to contract as it cools is vigorously opposed by the already cold and contracted exterior, and this resistance to its contraction tends to leave the interior porous; hence the lower specific gravity of the interior of pieces thus cooled. This struggle between the contracting interior and the comparatively rigid skin is the cause of the permanent longitudinal contraction of the piece. As the interior contracts, it tends both to draw the skin inwards and to shorten it. The resistance of the skin to a certain extent prevents the interior from contracting to its initial dimensions, while the pull of the interior compresses the skin both longitudinally and transversely. Acting lengthwise, it causes a permanent longitudinal contraction of the skin, just as an upsetting force from without would.

---

* See *Journal of the Iron and Steel Institute*, 1879, p. 418.

† *Transactions of the American Institute of Mining Engineers*, vol. xiv. pp. 400-403.

In order to test the matter, the conditions were altered, so that the changes of temperature were more sudden than in Wrightson's experiments, while hardly any contraction of the skin occurred after the skin had completely cooled and contracted. These conditions were obtained by suddenly cooling wires so thin that at each instant the temperature is practically uniform throughout their cross section, so that the interior and skin contract at practically the same rate, while the cooling is much more sudden than in thick bars. The results obtained show very slight contraction, owing to the almost complete elimination of the second period, and thus accord with the author's explanation. The results were as follows:—

Size of Bar or Wire.	Initial Length.	Number of Times Quenched.	Per Cent. of Contraction.	Observer.
	Inches.			
1⅛ inch square .	30·05	5 15	0.76 and 0·66 2·26 and 1·86	Wrightsou.
Hoop 1⅛ inch square	57·70	5 20	0·61 2·25	
No. 24, B.W.G. .	71·00	20	0·31	Howe.
No. 30, B.W.G. .	72·75	20	0·09	
No. 32, B.W.G. .	92·75	5	0·6	

The Porosity of Iron and Steel.—In order to fully understand the quality of iron or steel, chemical analysis alone is insufficient, and Dr. W. Thörner[*] considers that the physical examination should include—

1. The determination of the tensile strength and the elongation, and its resistance to pressure and blows. 2. The determination of the density. 3. The determination of the porosity. 4. There should be a microscopic examination of the texture of the metal. 5. The influence of magnetic action should be observed.

With regard to the relation existing between the porosity of the metal and its strength, the author gives the results of a series of investigations he has made on this subject. The porosity was determined in a similar manner to that already described[†] by the author in connection with the examination of coke and of charcoal, with the exception that it had to be done with greater care, as the presence of the slightest quantity of a foreign substance—such as hammer-scale—would cause the result to be absolutely untrustworthy. The liquid used in the volumenometer was alcohol, and it could be read off easily to 0·025 cubic centimetre. The iron cylinders examined weighed from 100 to 150 grammes each; and the iron powder, which was produced by careful filing, 30 to 40 grammes in each case.

In the tensile tests, test-pieces 200 millimetres long and 20 millimetres in diameter were employed. The results obtained were as follows:—

Metal Examined.	Specific Gravity of the		In 1 Kilogramme of Iron there were contained		Volume of 1 Kilogramme Iron (Cubic Centimetres).	Tensile Strength, Kg. per Sq. Mm.	Contraction, per Cent.	Elongation, per Cent.
	Iron Powder.	Iron Cylinder.	Cellular Space (Cubic Centimetres).	Space occupied by the Iron (Cubic Centimetres).				
1. Foundry pig iron . .	7·142	7·042	2·000	140·00	142·00	...	...	...
2. Bessemer rail steel .	7·812	7·722	1·500	128·00	129·50	54·5	53·8	15·0
3. Basic Bessemer ingot iron . .	7·968	7·813	2·500	125·50	128·00	46·1	59·0	27·0
4. Bessemer tyre steel .	7·784	7·737	0·730	128·28	129·01	62·5	53·0	22·9
5. Bessemer steel, for hard forgings .	7·983	7·908	1·230	125·23	126·46	78·0	38·5	18·0
6. Basic Bessemer steel .	7·752	7·700	1·580	128·42	130·00	56·5	45·3	15·0
7. Bessemer rail steel .	7·921	7·826	1·530	126·24	127·77	57·4	58·3	24·0
8. ,, ,, ,, .	7·755	7·729	0·530	128·95	129·48	56·5	52·0	20·0
9. ,, ,, ,, .	7·871	7·790	1·250	127·05	128·30	56·5	53·5	19·0
10. Basic Bessemer steel .	7·931	7·757	2·800	126·10	128·90	56·3	52·3	24·5

---

[*] *Stahl und Eisen*, vol. vi. pp. 166–168.

[†] *Journal of the Iron and Steel Institute*, 1885, p. 282.

With regard to the foundry pig examined, the author remarks that the microscopic examination showed that most of the pores were filled with slag, which accounts for the density and porosity that were found. Samples 8 and 9 were from the same charge.

These results show that the porosity of iron and steel may very easily be measured, and that it varies very greatly even in the same variety of steel. As a general rule, it appears that the porosity is in inverse ratio to the tensile strength, but this rule does not by any means hold good in every case ; this is easily to be accounted for owing to the pores being differently dispersed over the different portions of the ingot, and to the fact that a single test-piece would only give the mean tensile strength of the ingot in very exceptional cases.

By the term "porosity" the author understands only those pores which are of microscopic size, and he does not include in it the larger blowholes or hollows. He further remarks that if several test-pieces are taken from the same ingot and examined *seriatim*, that without doubt the tensile strength and the porosity would be found to be in a certain definite ratio to each other, and that it would be possible by this method of examination to obtain very interesting data concerning the exclusion of gases on the solidification of the metal, on the way in which the pores are scattered through the mass of the ingot, and also as regards its tensile strength.

The Properties of Iron.—A. Ledebur,* discussing generally the relations of iron to other elements, remarks on the liquation phenomena which frequently occur, especially in the case of ingot iron, and describes his experiments on this subject :—

Fifty grammes of steel were bored out of each of the three specimens of Bessemer ingot metal mentioned below, and were sifted through a fine brass sieve in order to separate the coarser from the finer particles, each of which was then submitted to chemical analysis. The results were as follows :—

EXPERIMENT I.

	Coarse Particles.	Fine Particles.
	Per cent.	Per cent.
Carbon	0·286	0·241
Silicon	0·864	0·944
Phosphorus	0·063	0·068
Manganese	1·100	1·218
Sulphur	0·040	Not determined
Copper	0·112	,,
Arsenic	trace	,,
Antimony	0·005	,,

---

* *Stahl und Eisen*, vol. vi. pp. 143–150.

EXPERIMENT II.

	Coarse Particles.	Fine Particles.
	Per cent.	Per cent.
Carbon	0·205	0·205
Silicon	0·305	0·321
Phosphorus	0·103	0·104
Manganese	0·594	0·613
Sulphur	0·064	Not determined
Copper	0·149	,,
Arsenic	0·009	,,
Antimony	0·005	,,

EXPERIMENT III.

	Coarse Particles.	Fine Particles.
	Per cent.	Per cent.
Carbon	0·294	0·252
Silicon	0·252	0·240
Phosphorus	0·050	0·073
Manganese	0·545	0·509
Sulphur	0·066	Not determined
Copper	0·103	,,
Arsenic	0·013	,,
Antimony	...	,,

As the analyses were made as carefully as possible, the author considers that the differences shown really exist, and are not due simply to analytical errors.

Specimens of the three samples of steel examined were submitted to physical tests with the following results:—

SPECIMEN I.

Tensile strength, tons per square inch	40·8	41·8
Contraction, per cent.	13	31·3
Elongation, per cent.	12·7	18·4

This sample of steel was exceedingly brittle.

SPECIMEN II.

Tensile strength, tons per square inch	34·05	34·5
Contraction, per cent.	52·8	53·5
Elongation, per cent.	23·6	24·4

The texture was very finely granular; with much smaller grains than that of Specimen I.

SPECIMEN III.

Tensile strength, tons per square inch	31·8
Contraction, per cent.	12·1
Elongation, per cent.	13·5

The grain of this sample was of average size; it was full of blowholes.

Samples of steel were submitted to slow solvent action, and the etched surfaces so obtained were examined under the microscope. Illustrations are given of photographs which were taken at the time. The gas channels are distinctly marked. A specimen of steel treated in this manner and found to contain a large number of blowholes, although before etching it appeared to be perfectly dense, was found to be a sample of silicon steel, as will be seen from the following analysis:—

Carbon.	Silicon.	Manganese.	Phosphorus.
0·176	0·612	0·708	0·166

The author has also analysed a bar which on fracture proved to have a star-shaped core of a different character to the external portion of the bar surrounding it. The star-shaped core was of fine grain, and was found to contain 1·246 per cent. of carbon; the outer portion of the bar was of larger grain, and contained only 0·860 per cent. of carbon. The percentage of silicon, manganese, and phosphorus was alike in each case.

The Changes in the Texture of Steel on Heating and on Cooling.—From a large number of experiments, over eighty of which were with samples of steel from the same Bessemer ingot, having the following percentage composition—

Carbon.	Manganese.	Silicon.	Phosphorus.	Sulphur.
0·52	0·48	0·13	0·026	trace

J. A. Brinell * draws the following conclusions: *—

1. If steel loses its coarsely crystalline texture without mechanical treatment, it is always due to the change of state of the carbon, either from cement-carbon to hardening-carbon, or *vice versa.*

2. The change of texture is only complete when the temperature to which the steel has been subjected is sufficiently high to convert the whole of the carbon into another form. In accordance with this is the complete change in the texture of coarsely crystalline steel, hardened

---

* *Jern-kontorets Annaler*, vol. xl., pp. 9–38.

or unhardened, when the exact temperature is reached which is sufficient for the conversion of cement-carbon into hardening-carbon.

3. In order to convert the carbon into cement-carbon, steel raised to a white heat must cool down slowly to a temperature below that to which unhardened steel must be raised in order to produce the same result.

4. The conversion of the cement-carbon into hardening-carbon occurs rapidly, as soon as the temperature is sufficiently high to permit of that result taking place. The change of state from hardening-carbon into cement-carbon, on the other hand, takes place much more gradually.

5. The change from hardening-carbon into cement-carbon is always accompanied by the evolution of heat, and it is therefore probable that, when cement-carbon is converted into hardening-carbon heat is absorbed, although the author was unable to substantiate this view in his experiments.

6. At the moment when the hardening-carbon changes into cement-carbon, either on heating or on cooling, crystallisation instantaneously sets in, and the fracture will be the more coarsely crystalline the more it was so originally.

7. Rapid cooling never produces an amorphous or finely crystalline fracture in the case of any steel which, at the moment before cooling was effected, was largely crystalline, but it prevents a steel which at the commencement of the cooling operation was either amorphous or finely crystalline from assuming a crystalline structure during the progress of the cooling. That is to say, rapid cooling only fixes the structure the steel possessed at the moment when it was acted on.

8. In order to convert hardening-carbon into cement-carbon, not only is the right temperature required, but also time; while in opposition to this, the conversion of cement-carbon into hardening-carbon only depends on the temperature. A consequence of this is that rapid cooling can prevent the change from hardening-carbon into cement-carbon.

9. For the crystallisation of the steel, too, not only is a certain degree of heat required but also a certain period of time; and as regards this latter, if the time during which the cooling is effected is diminished, either by plunging the steel into water, or by any other means, the formation of the crystals is either diminished or totally prevented.

The author observed the manner in which different varieties of iron and steel cooled down from high temperatures by noting the colour phenomena, and he found that in the first period of the cooling, steel cooled down more rapidly than iron, while in the later stages the opposite was the case, and he considers that this was due to the formation of crystals; crystallisation, however, being a form of work, heat is absorbed, and as steel crystallises more than iron does, more heat is absorbed in the case of steel than in that of iron, and consequently during the crystallising period the cooling is the more rapid in the case of steel.

The reason for the steel becoming hotter than the iron towards the end of the cooling is, in the author's opinion, due to the heat evolved on the conversion of the hardening into cement carbon, and in part also to the tendency of the steel to give up its crystalline form during the progress of the change in the state of the carbon. Hardening and annealing experiments were also made, as well as others in which the steel was attacked with nitric acid.

The Specific Gravity of Low Carbon Steel.—Mr. G. S. Miller * has made a series of determinations to find how the specific gravity of Bessemer steel compares with that of wrought iron. The steel from which the determinations were made was produced in four-ton heats, and cast into ingots of about 3100 lbs. weight, having an average section of 14⅞ inches square. These ingots were rolled in a blooming mill to a section of 2½ inches by 14 inches, cut into slabs and rolled in a plate-mill to a plate 0·065 to 0·165 inch thick, and about 14 inches wide. The specific gravity was obtained from pieces of this plate. The metal showed on analysis the following percentages :—

Carbon.	Manganese.	Sulphur.	Phosphorus.	Silicon.
0·10 to 0·12	0·33 to 0·45	0·06 to 0·072	0·075 to 0·082	0·01

The samples were not annealed, but were brought to a bright surface with a file. All figures given are averages of not less than three determinations on separate pieces from the same plate :—

Carbon per Cent.	Specific Gravity.			
	0·065 Inch Thick.	0·095 Inch Thick.	0·134 Inch Thick.	0·165 Inch Thick.
0·10	7·809	7·857	7·862	7·866
0·11	7·807	7·850	7·862	7·864
0·12	7·800	7·847	7·866	7·862
Average	7·805	7·851	7·843	7·864

---

* *Transactions of the American Institute of Mining Engineers*, vol. xiv. pp. 583–586.

The average of the whole number is 7·844. The specific gravity of iron similarly rolled to a thickness of 0·165 inch was found to be 7·680.

Determinations of thicker sections were made with the following results:—

Thickness.	Specific Gravity.
0·200 inch	7·860
0·224 ,,	7·866
0·300 ,,	7·865

From these figures it appears that the maximum specific gravity of a Bessemer steel containing 0·10 to 0·12 per cent. of carbon is attained when the metal is rolled to a thickness of 0·165 inch. The author deduces the specific gravity of a Bessemer steel with 0·10 to 0·12 per cent. of carbon, and 0·35 to 0·45 manganese, as 7·8635.

Mr. W. Kent * has made some determinations of the specific gravity of open-hearth steel boiler-plates, of analysis approximately as follows:—

Carbon.	Phosphorus.	Silicon.	Sulphur.	Manganese.
0·14	0·03	0·02	0·02	0·30

Five pieces of plate ¼ inch thick gave the following results:—

Specific gravity, 7·9328; 7·9320; 7·9318; 7·9356; 7·9275.
Average, 7·9319.
Maximum variation, 0·0081.

These figures tend to confirm Mr. Miller's observations that the thinner plate shows a lower specific gravity than the thicker, and that increase of impurity causes decrease in specific gravity.

The figures thus obtained by careful experiment on bright smooth pieces of steel are too high for use in determining the weights of rolled plates for commercial purposes. Experiments on commercial plates lead the author to adopt the figure 7·854 as the average specific gravity of best quality open-hearth steel. This figure is easily remembered as being the same figure with change of position of the decimal point (0·7854) which expresses the relation of the area of a circle to that of its circumscribed square, or one-fourth the ratio of the circumference to the diameter.

Influence of Temperature on the Strength of Iron and Steel.—The fact that low temperatures have considerable influence on the strength of metals, has great importance in reference to the strength of structures in cold northern countries. The results of experiments on this subject published by B. Papkoff * in the Russian mining journal are of interest, because they seem to point to conclusions totally opposed to those generally received.

---

* *Engineering and Mining Journal*, vol. xli. p. 167.

The specimens tested were taken from soft steel and iron plates, three samples being cut from each plate. One sample of each group was tested at the ordinary, and two at low temperatures, with the following results:—

	Material Tested.	Temperature. Degrees F.	Ultimate Strength in Tons per Square Inch.	Percentage of Elongation in 8 Inches.	Time of Exposure to Cold in Hours.
I.	Three strips of dephosphorised steel plate	+63½	22·73	25·9	...
		− 2	23·75	25·5	1
		− 2	26·10	27·6	3½
II.	Three strips cut out of iron plate, length with the grain .	+63½	17·91	10·1	...
		− 2	20·00	14·0	2
		− 2	19·30	16·3	2½

Both the ultimate strength and the percentage of elongation increase with the decrease of temperature. This result was to be expected, because the contraction caused by cooling has the effect of bringing the particles of matter closer together, and consequently of intensifying the force of cohesion. A law, however, which may be found general for strains gradually imposed, may not apply at all where they assume the nature of shock or of impact.

The Injurious Effect of a Blue Heat on Iron and Steel.—In a paper read before the Institution of Civil Engineers, Mr. C. E. Stromeyer † states that, in spite of the many excellent qualities possessed by mild steel, and in spite of its extended use for shipbuilding and for marine boilers, many engineers consider it a treacherous material. They are able to adduce numerous instances in which steel plates and bars have failed, in their opinion, in an unaccountable manner. In nearly all such cases a cursory examination brings out the fact, that the plates in question have been subjected to bending or hammering while hot, and there can be little doubt that while they were being worked these plates were at a blue heat, or, as smiths term it, a black heat. It should by this time be well known that such treatment is the most injurious to which steel can possibly be subjected, and therefore such failures cannot be properly regarded as unaccountable. Iron possesses the same peculiarity, but being less ductile than steel, similar failures are not so glaring.

---

* *Gorny Jurnal.*, 1885, p. 341; *Minutes of Proceedings of the Institution of Civil Engineers*, vol. lxxxiii. p. 513.

† *Minutes of Proceedings*, vol. lxxxiv. pp. 114–207.

Three hundred and thirty experiments were made in connection with the subject of the paper, and consisted mainly of bending and of tensile tests. It appears that the limit of elasticity of both iron and steel is raised by repeated tension testing. In some cases the limit rises above the original breaking stress, although the ultimate breaking stress is only slightly affected. The total elongation is reduced by previous mechanical operations, while the contraction varies considerably. A test-piece which had been shortened when cold showed a reduction of the elastic limit, but another piece which had been shortened when hot showed an increase. The expression "blue heat" includes all those temperatures which produce discolorations (ranging from light straw to blue) of the bright surfaces of steel or of iron.

The author shows that steel which had been bent cold either once or twice, will stand almost as many subsequent bends as the original test-pieces. But if the same material is bent once while blue-hot, it loses a great deal of its ductility. Out of twelve samples, in which two preliminary hot bends were made, nine broke with a single blow of a hammer, and the other three only stood one or two subsequent bends. Thin Lowmoor iron did not break quite so easily, but supported about one-half the original number of bends. The following table contains some of these results:—

	Medium Hard Steel, ⅜ Inch.	Mild Steel, ¼ Inch.	Very Mild Steel, ¼ Inch.	Lowmoor Iron, 3/16 Inch.
Unprepared or annealed	21	12½	26	20
Broken hot (blue)	2½	1½	2½	3
1 preliminary hot bend . . .	3 mean	2½ mean	11 mean	12 mean
2 ,, ,, bends . . .	½ ,,	⅓ ,,	⅔ ,,	10 ,,
1 preliminary cold bend . . .	20	9½	...	...
2 ,, ,, bends . . .	19½	8½	19	13
4 ,, ,, ,, . . .	...	...	13	11
8 ,, ,, ,, . . .	...	...	15	6

The experiments all point unmistakably to the great danger incurred if iron or steel is worked at a blue heat. The difference between good iron and mild steel seems to be that iron breaks more readily than steel while being bent; that iron suffers more permanent injury than steel by cold working, but that if it has successfully withstood bending when hot, there is little probability of its flying to pieces when cold, like mild steel.

It is a common practice amongst boilermakers to "take the chill out of a plate" if it requires a little setting, or to set a flanged-plate before it is cold. This is nothing else than working it blue-hot, and should not be allowed. All hammering or bending of iron and steel should be avoided, unless they were either cold or red-hot. Where this is impossible, and where the plate or bar has not broken while blue-hot, it should be subsequently annealed. It is satisfactory to learn that, since the introduction of mild steel, a practice had been gaining ground amongst boilermakers, which must have the effect of guarding against such failures, and should be encouraged. It consists in the cessation of work as soon as a plate, which had been red-hot, becomes so cool that the mark produced by rubbing a hammer handle or other piece of wood over it will not glow. A plate which is not hot enough to produce this effect, yet too hot to be touched by hand, is most probably blue-hot, and should under no circumstances be hammered or bent.

The theory that local heating of a plate sets up strains which sometimes cause failures, does not appear to be supported by the experiments. But it is doubtful whether the proposal to locally re-heat a plate which had been worked when hot, in order to anneal this part, should be carried out. Several test-pieces were made red-hot or blue-hot, and then were slowly cooled, by holding one of their edges in cold water. As might have been expected, the medium hard steel lost much of its ductility. The other steels and the iron were not greatly affected, as will be seen from the following table :—

	Medium Hard Steel.	Mild Steel.	Very Mild Steel.	Lowmoor Iron.
Unprepared or annealed . . .	21	12½	26	20
Quenched red-hot in boiling water .	24	10	...	...
,, ,, cold water . .	1	10	19	20
Red-hot, quenched edge in cold water .	3	8	25	27
Blue ,, ,, ,, ,, .	3	6½	19, 19	21, 14

The author concludes by suggesting that steel manufacturers should endeavour to ascertain whether every quality of steel is made permanently brittle by being worked at a blue heat, or whether this is independent of the various impurities contained in it; and also whether prolonged exposure to a blue heat can produce the same effect.

Peculiar Phenomena in the Heating of Open-Hearth and Bessemer Steel.—Mr. W. Garrett* claims that carbon in a steel bloom is not affected by burning or overheating the steel. In order to prove this he gives a case in point, which is an illustration how established theories are sometimes proved by accident to be wrong. On one occasion, at the works of the Cleveland Rolling Mill Company, the lever of the damper broke, and the damper fell off the stack. In the furnace were 5-inch blooms to be rolled into 1½ inch square for spring-steel (the carbon was 0·74). The heat was just about ready, and the heater had just put on a heavy fire, and was putting the damper down when the lever broke. He in his fright did nothing but pull the doors up. Meanwhile the heat was getting higher, and by the time the author arrived the blooms had got so hot that the top side of them had melted. The grate-bars were at once taken out. The furnace and steel began to cool; but the 4000 lbs. of steel in the furnace were regarded as ruined. Some of the blooms, however, next the flue being in pretty fair shape, they were rolled from there, the intention being to stop as soon as the blooms began to break up in the rolling. Every bloom in that heat rolled well, although some were so much out of shape that they could hardly be placed in the rolls. A sample of the bloom that was most burnt proving on testing to be satisfactory, and 500 lbs. were rolled as a sample lot. This proved to be first-class steel; the balance was shipped, and no complaint arose. An assay of the billet gave 0·74 per cent. of carbon, the same as the carbon of the cast. This result was confirmed by a number of experiments.

The author confines his assertion that steel will not be rendered brittle, nor lose any of its properties by overheating, to Bessemer, open-hearth, and Clapp-Griffith's steel, and that only after it has been bloomed.

The Structure of Tempered Steel.—C. Barus and V. Strouhal † publish a typical example of the results they have obtained.

The steel cylinder (length 6 centimetres, diameter 3 centimetres, weight 332 grammes), to which the data refer, was quenched glass-hard in the ordinary way. The consecutive cylindrical shells were then removed by galvanic solution, and the necessary measurements made to determine the density of each. Let Δ be the density (0° C.) of the consecutive cores, and R, θ, δ, the mean radius, thickness, and density respectively of the consecutive shells. Then if the nth core be left after the removal of n shells, the table gives the digest in question :—

---

* Paper read at the Pittsburg meeting of the American Institute of Mining Engineers, February, 1886.—*Transactions*, vol. xiv. pp. 789–795.

† *American Journal of Science*, vol. xxxi. p. 386.

Shell or Core No.	Δ.	R.	θ.	δ.	Remarks.
0	7·8337	...	...	...	Before quenching.
0	7·7744	...	...	...	After quenching.
1	7·7734	1·49	0·02	7·807	...
2	7·7727	1·47	0·03	7·783	...
3	7·7742	1·43	0·03	7·739	...
4	7·7734	1·40	0·03	7·794	...
5	7·7750	1·37	0·03	7·733	...
6	7·7784	1·33	0·05	7·737	...
7	7·7813	1·28	0·05	7·743	...
8	7·7817	1·23	0·05	7·776	...
9	7·7841	1·19	0·03	7·735	...
10	7·7869	1·15	0·05	7·751	...
11	7·7894	1·10	0·05	7·762	...
12	7·7919	1·05	0·05	7·764	...
13	7·7911	1·00	0·05	7·800	...
14	7·7937	0·96	0·04	7·760	...
15	7·7979	0·92	0·04	7·745	...
16	7·7999	0·88	0·04	7·776	...
17	7·8017	0·84	0·04	7·781	...
18	7·8013	0·80	0·05	7·805	Core perceptibly fileable.
19	7·8027	0·75	0·05	7·792	...
20	7·8009	0·69	0·07	7·811	...

Tensile Tests of Iron and Steel Bars.—A series of tests was made by the late Mr. P. D. Bennett * at the Horseley Ironworks, Tipton, his principal object in making these tests being to ascertain the relative effect produced on the tensile strength of a flat bar of iron and steel—

1. By a hole drilled out of the bar to the required size.
2. By a hole punched ⅛ inch smaller in diameter and then drilled out to the size of the first hole.
3. By a hole punched in the bar to the size of the drilled hole.

The test-pieces in each series were cut from separate and complete bars, and each variety was taken from three different parts of the bars. The centre and end pieces were left unperforated, and were tested in order to supply the basis of comparison for the perforated pieces, and also in order to check the homogeneous quality of the entire bar.

When the bar of iron experimented upon was perforated by a drilled hole of ¾ inch diameter, the tensile strength across the part fractured was increased from an average of 24·54 tons per square inch of the original area in the unperforated bars, to 25·26 tons in the drilled bars. When the bar experimented upon was perforated by having a ⅝ inch hole punched in it, and afterwards drilled out to ¾ inch in diameter, the average strength was increased from 24·54 tons to 25·28 tons per square inch of the original area across the fracture. This shows that the method of perforating the bars in these two cases did not materially affect the strength of the iron under test, both methods giving results nearly identical and slightly above the strength of the unperforated bar. But when the bar was perforated with a hole punched out to the full ¾ inch in diameter, the tensile strength averaged only 19·53 tons per square inch, as against 24·54 tons in the unperforated bar, thus showing a falling off in strength of more than 20 per cent. owing to the method of perforation. Taking the strength of the unperforated bar as unity, the relative strengths of the perforated bars were as follow:—

---

* *Institution of Mechanical Engineers, Proceedings*, 1886, pp. 44–61.

Unperforated bar of iron	1·000
Perforated by drilling	1·029
Perforated by punching and drilling	1·030
Perforated by punching only	0·795

A second series of tests was exactly similar to the first, except that the metal tested was mild steel instead of iron. The results of these tests, confirming the preceding, show that the bars perforated with a drill-hole, and with a smaller punched hole drilled out to the same size, were slightly stronger than the unperforated bar, but that more than 6 per cent. loss of strength ensued when the hole was punched out to the full size. The relative tensile strengths per square inch of original area in these tests were as under:—

Unperforated bar of mild steel	1·000
Perforated by drilling	1·068
Perforated by punching and drilling	1·059
Perforated by punching only	0·935

The third series of tests was exactly similar to the first, except that the perforated hole was filled with a rivet put in by a hydraulic machine with a pressure of 31 tons on the head. The results of these tests again confirm the first, though the putting in of the rivet diminished by about one-half the loss of strength due to perforating the bar by punching only. The relative tensile strengths per square inch of original area in these tests were as under:—

Unperforated bar of iron	1·000
Perforated by drilling and filled with rivet	1·012
Perforated by punching and drilling and filled with rivet	1·008
Perforated by punching only and filled with rivet	0·894

The fourth series of tests was exactly similar to the third, except that the metal tested was mild steel instead of iron. The results were similar to the above, the relative tensile strengths per square inch of original area being as given below :—

Unperforated bar of mild steel	1·000
Perforated by drilling and filled with rivet	1·103
Perforated by punching and drilling and filled with rivet	1·110
Perforated by punching only and filled with rivet	0·927

From each of these four tables it will be seen that the metal withstood a slightly greater tensile strain per square inch of original area across the drilled hole than it did across the unperforated bar. This no doubt was owing to the fact that in the drilled bar the slightly greater strain indicated in the tables was reached only along the transverse diameter of the hole, and that the strain on the metal decreased along the longitudinal diameter of the hole, until it was distributed over the whole width of the bar. Thus at the point where it was most severely strained the metal would receive some support from the less severely strained parts adjoining.

This conclusion is confirmed by a fifth series of tests, which show that when a round iron bar of 1½-inch diameter was reduced in diameter to 0·84 inch at one point only, it fractured under a much greater tensile strain than when it was turned down to the same diameter throughout a length of 10 inches. The relative tensile strengths per square inch of original area in the two cases were as under :—

Round iron bar turned down to 0·84 inch in diameter through 10 inch length	1·000
Round iron bar grooved to 0·84 inch in diameter at one point only	1·323

The elongation of different test bars, all of the same length, is greatly affected by their diameter, those of larger diameter elongating more than those of smaller diameter.

A sixth series of tests was made on flat steel bars, to ascertain whether the method of holding the ends of the specimens under test, by grips or by pins, had any effect upon the results of the tests. The figures show that there was a slight advantage in favour of holding the ends by means of grips, instead of by pins passing through, the average breaking strain with the grips being 30·11 tons per square inch of original area, and with the pins 29·97 tons.

A seventh series of tests on flat bars of mild steel showed how the length of the specimen under test affects the tensile strength, elongation, and contraction of area at the point of fracture. As the specimens decrease in length the contraction of area at the point of fracture decreases also; and in consequence the tensile strength increases, when reckoned on the original area, and decreases when reckoned on the fractured area. The elongation in percentage of the original length is also very much increased in the shorter specimens, owing to the fact that the greater part of the elongation then takes place much nearer to the point of fracture, instead of being more equally distributed, as it is along the length of the longer bars.

The Present Value of Steel Castings.—Mr. A. V. Abbott* has had occasion to use steel castings to a large extent in the manufacture of testing machines and large scales for Messrs. Fairbanks & Co. The failure of some of these castings at stresses much below those claimed for them by the makers, induced him to institute a series of experiments to determine the actual constructive value of the steel castings now in use in America.

Two patterns were sent to each of ten firms who advertised to make steel castings, one pattern being a straight bar 2 inches square and 30 inches long, the other a bar 1½ inch square for a distance of 6 inches on each end, and turned for a space of 12 inches in the centre. Two castings were ordered from each pattern. From only seven of the ten manufacturers samples were received. The results of tests in tension, compression, and transverse strain were as follows:—

No.	Tension.				
	Elastic Limit.	Ultimate Limit.	Elongation.	Reduction.	Modulus.
	Lbs. per sq. in.	Lbs. per sq. in.	Per cent.	Per cent.	Lbs.
1	28,923	43,631	6·00	0·72	25,150,000
2	25,610	36,880	0·40	0·82	24,000,000
2	25,650	42,280	0·80	1·20	21,000,000
3	23,116	44,221	6·00	...	18,000,000
4	21,395	38,301	10·00	...	23,773,000
6	31,180	46,156	2·00	...	27,600,000
7	35,840	56,724	10·00	2·07	25,150,000
9	35,445	52,330	9·00	1·47	28,325,000
9*a*	38,217	63,058	29·88	19·88	...
9*a*	38,217	62,816	20·50	18·18	...
10	17,522	32,151	8·00	3·42	20,000,000

---

* Paper read at the Halifax meeting of the American Institute of Mining Engineers. —*Transactions*, vol. xiv. pp. 351–358.

No.	Compression.		Transverse.			
	Elastic Limit.	Modulus.	Elastic Limit.	Ultimate Lim.	Deflection.	Modulus.
	Lbs. per sq. in.	Lbs.	Lbs. per sq. in.	Lbs. per sq. in.	Inch.	Lbs.
1	35,011	23,333,000	6,000	8,000	0·72	20,000,000
2	31,250	30,000,000	2,500	3,870	0·45	19,000,000
2	...	...	2,600	3,950	0·52	19,000,000
3	24,350	19,000,000	3,000	4,181	0·88	20,830,000
4	26,750	20,600,000	3,750	5,720	0·15	20,550,000
6	29,703	21,000,000	4,000	6,259	0·60	20,000,000
7	36,110	24,000,000	4,000	5,480	0·20	25,000,000
9	27,027	20,800,090	4,000	6,810	0·21	28,000,000
10	20,408	19,000,000	2,500	4,010	0·35	20,000,000

The tests marked 9*a* were submitted to the United States Navy Yard as samples of steel casting to be furnished for naval construction.

The average of the tension tests were: elastic limit, 29,000 lbs., elongation, 9 per cent., and modulus, 24,443,000 lbs. With the exception of the elongation, which is low, these results show that the material is equal to good iron. In comparison with cast iron, the material is at least three times as efficient for constructive purposes.

The results of the transverse tests are similar in character, excepting that, subjected to this form of stress, the lack of ductility tells badly against the material. In compression the hardness and rigidity of the material make it compare still more favourably with wrought metal, especially where it is to be used under circumstances free from lateral or bending stresses.

The author concludes that for parts of machinery that are subjected to anything but direct compression, the steel casting, as at present made, may be considered the successful rival of forged work. Where, however, compression is alone to be resisted, cast iron will hold its own for a long time to come; for, subjected to this stress, steel is but little superior to iron, and the great difference in price will long continue to make iron the successful competitor.

The Use of Ingot Iron for Boiler and Ship Plates.—In a paper read at the general meeting of the Mining and Metallurgical Association of Styria and Carinthia, P. von Tunner * states that at the Styrian works the material which is considered best adapted for boiler-plate is ingot iron, having a tensile strength of 40 to 45 kilogrammes per square millimetre, and an elongation of 20 to 25 per cent. on a length of 200 millimetres; such a metal contains from 0·1 per cent. to 0·20 per cent. of carbon; and a rod made of it, after heating to redness and quenching in cold water, may be bent 130° to 150° without breaking, provided that the surface of the bar has not been indented, in which case it breaks much more rapidly, as the cut surface, not being able to stretch, prevents the adjoining layers from stretching, the consequence being that the bar tears. The slag and other impurities present prevent this happening in the case of weld iron.

---

* Oesterreichische Zeitschrift für Berg- und Hüttenwesen.—*Beilage*, vol. iv. p. 75.

Recent Failures of Steel Boiler-Plates.—A most startling failure of steel boiler-plates in two different sets of boilers is reported by Mr. A. J. Maginnis. The facts of the case are as follows:—

The material used for two sets of boilers on two steamers, each set consisting of three circular boilers with two horizontal steam-chests, passed all the tests required by the Board of Trade and Lloyds. The material stood satisfactorily the ordinary work of the boiler-shop, including welding. Each set of boilers worked at sea for two and a half years most satisfactorily, after which they exhibited signs that a complete change had taken place in the nature of the steel. The signs of failure were extensive cracks. When testing the result by striking the cracked portions with a sledge-hammer, the first blow extended one of the cracks about 4 inches, leaving only 2½ inches more of solid plate. This remaining portion was then hammered flat, and again straightened without in the least extending the crack. A piece of the second plate was struck one blow, and snapped off like glass. The boilers were then condemned, and the results of breaking them up were indeed startling. The pipes were found to be cracking in all directions; and when the furnace and front plates were started upon, a general smash was experienced.

The last records of the plates before leaving the works show results as follows:—The thickness of the plates tested varied from 0·41 in the steam-chest plates to 0·74 inch in the shell plates; the tensile strength, from 58,332 to 68,095 lbs. per square inch; the greatest elongation was 27 per cent. in 10 inches, and the lowest 19·95 per cent. An inspection of the forty tests made shows that eight plates were between 58,000 and 60,000 lbs. tensile strength; twenty-four plates were between 60,000 and 64,000 lbs., and eight plates were between 64,000 and 68,095 lbs. Twenty plates showed elongation between 19·75 and 22 per cent.; eleven plates between 22·5 and 24·5 per cent.; and nine plates between 25 and 27 per cent.

Pieces were cut from the cracked plates of the combustion chambers, and the tests show the following results:—

Steamer No. 1.	Four Tests.			
Tensile strength	103,430;	106,400;	90,720;	104,026 lbs.
Elongation	8	7·75	13	15 per cent.

Fractures all finely crystalline.

Steamer No. 2.	Seven Tests.						
Tensile strength	58,026;	54,298;	56,837;	57,120;	60,122;	60,032;	56,851 lbs.
Elongation	15	24·5	22	17·25	26	26·75	8 per cent.

Fractures all fibrous, silky, fine.

Chemical analyses gave the following results:—

	Steamer No. 1.	Steamer No. 1.	Steamer No. 2.
Carbon	0·125	0·125	0·175
Silicon	0·005	0·018	0·018
Manganese	0·320	0·530	0·370
Sulphur	0·051	0·043	0·045
Phosphorus	0·060	0·061	0·068

The material, chemically, is not at all objectionable, being of good average quality.

The theories brought forward to account for the failure are summarised by Mr. W. Kent * as follows:—(1) Internal strains; (2) Homogeneousness; (3) Crystallisation; (4) Internal deterioration; (5) Large plates; (6) Bessemer steel untrustworthy; (7) Insufficient work in ingots; (8) Improper manipulation of plates.

Mr. Kent is unwilling to accept any of these theories as sufficient to explain the failure, and is of opinion that the most probable cause of the so-called mysterious failures of steel boiler-plates is not their homogeneity, but their heterogeneity; this being caused by imperfect mixture of the re-carboniser with the mass of molten steel before casting.

A Test of Boiler Steel.—Mr. Henry Schlacks,† superintendent of motive power of the Illinois Central Railroad, uses a shop-test by drifting. A ⅝-inch hole is drilled in one corner of a piece ⅝ inch from each side and then drifted out. If the hole can be enlarged to 1¼ inch when the crack has just opened from the side to the hole, it is good material. A ⅝-inch hole in the centre of a piece 3½ inches wide should drift out to 2½ inches to 2¼ inches when the crack runs from the side to the hole. But in the drifting test everything depends on the drifts and weight of sledge. The smaller or first drift should be not less than 12 inches long, ⅝ inch at small end, and 1 inch at large end, and finished on a lathe. The second drift should be 16 inches long, ⅞ inch at small end, and 1½ inch at large end, while the third drift may be 18 inches long, and 1⅛ inch at small end, and 2¾ inches at large end. A hammer not heavier than 4 lbs. should be used, and the drifts should be oiled and driven from both sides, with not more than four or five blows on either side at a time. If the drifts be short and blunt and the hammer 16 or 18 lbs., the enlargement of the hole at each blow is so instantaneous that the strain exceeds the strength of the steel, and even copper, under these circumstances, may be broken before it has drifted 1/16 inch. With light hammer and drifts, as described, a very satisfactory rough test is obtained for the ductility of steel.

---

* *Transactions of the American Institute of Mining Engineers*, vol. xiv. pp. 812–826.

† *Iron Age*, vol. xxxvii. No. 6.

Mild Steel for Shipbuilding.—At the twenty-seventh session of the Institution of Naval Architects, two important papers on this subject were read by Mr. B. Martell and Mr. J. Ward.

It is now eight years since mild steel began to be used for shipbuilding, but the progress that it has made during the past three years has been remarkable. In 1884, out of 895,455 gross tons of iron and steel vessels launched, 151,339 tons were of steel; but in 1885 the proportion was 223,288 tons out of 516,053 tons; while of the vessels under construction or contracted for on January 1, 1886, 156,267 tons were of steel, out of 318,567 tons. Mr. Ward shows that prior to 1880, at the Leven Shipyard, Dumbarton, 7000 tons of mild steel were used, embracing 58,000 separate pieces of material, and of these only six plates and one angle bar failed; while since 1880, 48,000 tons have been used, consisting of 350,000 pieces, and of these seven plates and two angle bars have failed. More than four times this amount has often been lost in a single iron vessel. Steel does not require nursing. It can stand the amount of rough usage it is sure to get in a shipyard in punching, shearing, hammering, and furnacing as well as iron; if this were not so, and special precautions were necessary for working it, this necessity could not but bring about its certain failure and rejection, as no amount of instruction would ever gain it better or different treatment, at the hands of the workmen, than iron always had. Mild steel suffers much less from local heating than is generally thought; indeed, under conditions of local heating, or even blue heat, failures in shipyards of open-hearth steel are the rare exception and not the rule. The use of iron rivets in steel steamers is to be deprecated, though Lloyd's still allows the option of either steel or iron rivets, but under the late Liverpool Registry steel vessels were compelled to be riveted with steel rivets, and a similar practice is carried out in all recent Admiralty work. It is hoped that this matter will receive early recognition at the hands of Lloyd's Register, and thus give steel vessels all the benefit of constructive thoroughness they are entitled to.

Severe and injurious strains are not brought on the plates in the immediate vicinity of the rivet holes through riveting and cutting out, for either the annealing effect of a hot rivet counteracts this, or the injury is purely imaginary. The results of galvanising steel plates as a preservative against corrosion are highly satisfactory; there is also the advantage gained of a slight increase in tensile strength without any material reduction in its ductility. With iron plates, however, galvanising has a weakening effect, so far as the experiments at the Leven Shipyard are concerned.

Steel for Structural Work.—Mr. James Christie read a paper upon "The Adaptation of Steel to Structural Work" before the Engineers' Club of Philadelphia. He remarks that the price of steel has now fallen so low, as compared with iron, that its increased use will be actively stimulated as the building industries revive. The grades and properties of the steels are so distinct and various that opinions differ much as to the adaptability of each grade for a special purpose. Hitherto engineers have favoured open-hearth steel on account of uniformity, but recent results obtained from Bessemer steel tend to place either make on an equality. The tendency is to specify what the physical properties shall be, and not how the steel shall be made. For boiler and ship plates the mildest and most ductile steel is favoured. For ship-frames and beams a harder steel, up to 75,000 lbs. tenacity, is frequently used. For tension members of bridges, steel of 65,000 to 75,000 lbs. tenacity is usually specified, and for compression members, 80,000 to 90,000 lbs. In the Forth Bridge, compression steel is limited to 75,000 to 92,000 lbs. Such a marked advantage occurs from the use of high-tension steel in compression members, and the danger of the sudden failure of a properly made strut is so little, that future practice will favour the use of hard steel in compression, unless the material should prove untrustworthy. In columns even as long as 40 diameters, steel of 90,000 lbs. tenacity will exceed the mildest steel 35 per cent., or iron 50 per cent. in compressive resistance. The present uncertainty consists largely as to how high-tension steel will endure the manipulation usual with iron without injury. A few experiments were recently made by the author on riveted struts of both mild and hard steel, which had been punched, straightened, and riveted as usual with iron, but no indication of deterioration was found. Steel castings are now made entirely trustworthy for tensile working stresses of 10,000 to 15,000 lbs. per square inch. In some portable machinery an intermittent tensile strength is applied of 15,000 lbs., sometimes rising to 20,000 lbs. per square inch of section, without any evidence of weakness.

The Weight and Section of Rails.—A Committee of the Roadmasters' Association of the United States has submitted the following report: *—

1. *Weight.*—For the rail of the quality at present manufactured, and to suit the present spacing of cross-ties, the committee would recommend two standard weights—60 lbs. per yard for light and 70 lbs. per yard for heavy traffic.

2. *Form.*—They would recommend that the form be substantially that shown in a drawing accompanying the report, the base to be equal to the height, and the radius of the top of the head to be the same as that of the fillet of the wheel, ½ inch preferred.

3. *Joint.*—They do not feel prepared as yet to recommend a joint. The double angle splice makes a superior joint, but inasmuch as this subject is at present receiving considerable attention in railroad circles, and as there are good forms of joint which merit attention, they would recommend that it be discussed and continued to the next meeting.

The section adopted is the same as that employed by the Pennsylvania Railway, and has a radius of ⅝ inch, the height of the rail being 4·5 inches and the width of the web 0·5 inch; the radius of the upper part of the head is 12 inches.

With regard to rail-joints, that manufactured by Mr. Clarke Fisher forms a bridge across two ties laid six inches apart in the clear, and the rails are fastened to it by means of a U-bolt, which holds them in place, and prevents them from working up and down under every passing wheel. The Association finally decided that the length of the angle-joint should be 44 inches, or to reach three ties with a tie under the centre.

Some of the members of the committee were of opinion that the question of the best weight for rails was an open one, while others thought that it should depend on the amount of traffic which would have to pass over it, and that to insure the necessary stiffness a 75-lb. rail would probably be the best to use.

---

* *Iron Age*, vol. xxxvi., No. 18.

Tensile Tests of Winding Ropes.—A. Kás * has experimented at considerable length with different kinds of winding ropes, the ropes being either (1) new, (2) old but unfrayed, or (3) frayed, this last class being again subdivided according to the position of the broken strands. The experiments showed that the tensile strength of the rope was not, as is frequently supposed, diminished by the twisting together of the different strands, but that the opposite was the case, the tensile strength being slightly increased.

An Autographic Test-recording Apparatus.—The apparatus described by Mr. J. H. Wicksteed † is applicable to any testing machine where fluid pressure is employed, and is so sensitive as even to register on the diagram any stresses casually induced upon a sample by irregular manipulation of the machine.

The autobiography written by every specimen of iron and steel that is strained to the breaking point in the testing machine may be summarised as follows:—Supposing it to enter the machine in a state of ease, having no unequal stresses among its particles, its first stage is one of what has been called in this paper unyielding elasticity; it extends about 0·0001 of its length per ton of load, but on the removal of the load it shows itself unstrained, recovering its former dimensions. During this period the equilibrium of stress is stable, and uniform throughout the sample. Its second stage is a state of fluctuating strains and stresses. The bar yields about 2 per cent. of its length; and this strain is beyond recovery. The pencil of the indicator hesitates and almost trembles. There would seem to be a succession of local extensions in the bar, as was lately pointed out by Professor Kennedy. These local extensions evidently reduce the area locally in a higher ratio than the cohesive force increases; hence a condition of unstable equilibrium, which would lead at once to fracture, were it not that after a short critical interval the bar sets up increased resistance, and thus enters its third stage. Here stable equilibrium is restored; but the permanent strain increases in its ratio with every added ton, so that in the latter part of this stage the bar suffers as much extension from 1 ton as it does in the earlier part from 5 tons. During this stage the bar may stretch about 20 per cent. of its length.

---

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxiv. pp. 171-175 and 192-194.

† *Institution of Mechanical Engineers, Proceedings*, 1886, pp. 27-43.

The fourth stage is the last. The instability of the equilibrium recurs, but is not critical or fluctuating as in the first notable yielding of the bar. There is no indecision in the pencil, but it steadily records a rapidly decreasing resistance, accompanied by a local strain which over the part where it occurs is very much greater than in any preceding stage. For although the local extension over this part may be only 5 per cent. of the total length of the bar, it would, if contributed in the same proportion of the bar generally, be found to amount to about 80 per cent. of the original length.

The autographic record appears to possess the following advantages of the utmost practical importance:—

1. It records definitely and beyond question the load at which the material gives out in its elasticity and yields irrevocably under the stress.

2. The area of the diagram gives the gross mechanical value of the material.

3. By enabling the local extension about the breaking point to be separated from the general, it affords a means of making just comparisons between samples of different shapes. Only their initial sectional area needs to be known, and the scale of the diagram drawn to suit it. By this simple plan, whatever the size of the specimen may have been, the diagram can be read off throughout its stages in loads per square inch.

New Apparatus for Measuring the Modulus of Elasticity.— At a recent meeting of the Berlin Physical Society Dr. König exhibited a new apparatus for the measurement of the modulus of elasticity, which was constructed according to the suggestions of Professor von Helmholtz. The modulus of elasticity was determined by loading in the middle a bar of the substance to be examined, resting both ends on firm supports. The flection that set in was measured by means of the cathetometer, and its value being introduced into the formula of the elastic theory furnished the modulus of elasticity. A source of error in these measurements arose from the circumstance that the bar resting on edges was in part pressed in and sank as a whole. This depression was the greater as the loading was greater, and it added to the magnitude of the deflection. To avoid this disturbance in the account Professor Kirchhoff, in 1859, placed horizontal mirrors on the two ends of the bar, and by means of telescope and scale observed at each side the change in situation of each mirror, a change that occurred in consequence of the deflection under the loading in the middle, and which produced on both sides an opposite displacement of the scale. The sinking of the bar on account of the pressure on the edges, and even a slanting position on the part of the whole bar, exercised no influence on these measurements. The apparatus suggested by Professor von Helmholtz develops this principle still further. It has two perpendicular mirrors, with the reflecting surface directed inward at the two ends of the bar; on one side stands a scale, on the other a telescope. The image of the scale falls on the opposite mirror, then on the second mirror, and thence into the telescope. If, now, the bar is loaded so that deflection occurs, then the image in the telescope becomes displaced to the extent corresponding with the angular changes of the two mirrors. By glancing, therefore, into the telescope the whole amount of deflection may be measured very rapidly and conveniently, and the loading altered at pleasure. The commencement of the elastic after-effect may likewise be directly observed with great facility.

Bending Cast Iron.—The *Scientific American* describes the method adopted in bending a flat iron casting weighing 300 lbs. which required two turns or bends in its length. Where the bends were to be made alcohol lamps were placed, the piece being suspended above them. After the under side of the casting had been heated to a degree that would have drawn hardened steel to a straw colour, a pressure by the aid of a weighted lever was applied to the upper surface of the casting, and the lamps being moved from point to point the iron yielded to the pressure and the heat, a curve being made that could not have been finished by planing, and yet the casting retained its finish, the discolouration due to the lamps being removed by rubbing it with emery-cloth. In another instance a crooked casting was about to be thrown on the scrap-heap at a loss of about 100 dollars, but was straightened by the careful use of two gas flames diffused by wire gauze, pressure being applied to the surface of the casting. It is quite possible to bend or to straighten cast iron to a very appreciable degree by the careful use of a very low degree of heat, under the simultaneous action of a carefully applied stress.

CHEMICAL PROPERTIES.

The Action of Certain Acids and Salts on Iron and Steel.—G. Lunge * describes the results of numerous experiments on the above subject. He shows that at ordinary temperatures and pressures strong sulphuric acid is without any very appreciable action, but that at 100° the action is much stronger. The weaker acids have a very much more powerful action, that of 50° B. being about fourteen times that of 66° B. acid at the temperature of 295° C.

Different varieties of iron were found to possess very different degrees of resistance to the action of the acids at the temperatures of their boiling points, charcoal pig iron and chilled castings being much less affected than the other varieties. Amongst these latter the relations are more complicated. Scottish pig iron and the mixture of this with one-half hæmatite pig iron were most attacked.

The relative action of solutions of common salt, of chloride of ammonium, of caustic soda, of sodium sulphide, and sodium sulphate on cast iron and on wrought iron were also examined. The wrought iron was, in each case, much more readily attacked than the pig iron, except in the case of the sodium sulphide solution, by which the cast iron was more readily attacked, and it was found that the chloride of ammonium solution had much greater action than that of common salt.

The Action of Caustic Soda on Iron and Steel.—W. Venator † has examined the action exerted by caustic soda on iron and steel. The experiments included the action of solutions of soda of varying concentration, as well as that of fused soda.

Thin plates of steel were rapidly dissolved, and the action was in every case greater when the surface of the metal was clean than when it was oxidised. The relative action of a 57·5 per cent. solution of caustic soda on different varieties of iron and steel will be seen from the following tables, the first of which shows the analyses of the metal, and the second the decrease in weight after three successive periods of attack, each lasting 72 hours :—

---

* *Chemisches Repertorium*, vol. x. p. 86.

† *Chemiker Zeitung*, vol. x. pp. 319–321 and 389–390.

	Carbon.	Silicon.	Phosphorus.	Sulphur.	Manganese.
1. Cast iron . . .	3·150	1·980	0·724	0·049	0·540
2. Wrought iron . .	0·040	0·026	0·102	0·132	...
3. Wrought iron . .	0·041	0·035	0·104	0·029	...
4. Steel. . . .	0·365	0·182	0·007	0·007	...
5. Ingot iron. . .	0·123	0·186	0·065	trace	...
6. Weld iron. . .	0·072	0·135	0·055	trace	...

	Original Weight.	Surface.	Decrease in Weight after			Total Decrease.
			72 Hours.	144 Hours.	216 Hours.	
	Grammes.	Square centimetres.	Grammes.	Grammes.	Grammes.	Per cent.
1. Cast iron . .	59·4770	32	0·3105	0·0715	0·0910	0·79
„ „ . .	48·1945	32	0·4005	0·1750	0·0955	1·40
2. Wrought iron .	53·4586	32	0·3756	0·2980	0·1042	1·43
„ „ .	53·9310	32	0·3265	0·2827	0·3083	1·69
3. Wrought iron .	66·9980	88	0·5070	0·3010	0·3400	1·71
„ „ .	64·2930	88	0·4490	0·2144	0·2320	1·39
4. Steel . . .	48·5715	32	0·1290	0·0835	0·0450	0·52
„ . . .	48·9545	32	0·1175	0·0955	0·0605	0·54
5. Ingot iron . .	50·3830	32	0·2474	0·1336	0·0570	0·89
„ „ . .	48·1860	32	0·2520	0·1055	0·1185	0·99
6. Weld iron . .	49·9875	32	0·3820	0·1545	0·1925	1·48
„ „ . .	51·4665	32	0·2585	0·1130	0·1385	0·99

CHEMICAL ANALYSIS.

CONTENTS.

	PAGE		PAGE
I. Analysis of Iron and Steel .	388	III. Analysis of Fuel	402
II. Analysis of Iron Ores and Slags	400	IV. Gas Analysis	404

I.—*ANALYSIS OF IRON AND STEEL.*

The Sampling of Cast Iron Borings.—The amount of graphite mechanically mixed in cast iron borings is quite large enough to cause serious difficulty when the problem is to obtain an average sample of a given lot of borings for carbon determination. Mr. P. W. Shimer * has overcome this difficulty in the following way:—The borings are carefully poured out into a large porcelain crucible or dish, and enough alcohol added to merely moisten them (2 cubic centimetres of alcohol to 30 grammes of borings). Mix thoroughly for five minutes. Remove with a spatula as many samples of the moist borings as are needed, weighing them out roughly. Dry off the alcohol and weigh accurately. The samples thus obtained represent the average of the original sample, for the alcohol simply serves temporarily to hold the graphite where it belongs, upon the surface of the borings. Alcohol sufficiently pure for the purpose can easily be obtained.

The following total carbon results show the value of the method:—

	I.	II.
Mixed dry in the bottle	3·68	3·84
Moistened with alcohol and mixed	3·97	3·99

It was suggested by Mr. F. Firmstone to determine whether or not there is any appreciable loss of graphitic dust while making cast iron turnings according to his method, in which the turnings are taken equally from the whole section of a piece of pig iron; the outside being first removed. The following are the total carbon results from samples:—

---

* Paper read at the Pittsburg meeting of the American Institute of Mining Engineers, February 1886.—*Transactions*, vol xiv. pp. 760–763.

I. Turnings taken dry, but sampled moist. II. Turnings taken moist. III. Thin section.

I.	II.	III.
4·132	4·122	4·031
4·123	4·123	4·038
4·111	4·103	4·108

The results under I. and II. show that there is no appreciable loss of graphitic dust. The first two results on the thin section are low, because of incomplete decomposition of the iron when, after forty hours, hydrochloric acid was added to complete the solution. The third result is about right; but complete decomposition was obtained in this case by long-continued stirring.

In sampling ores, the author moistens with water before mixing. This secures a uniform mixture of coarse and fine parts, from which a true sample can easily be removed.

The Determination of Phosphorus in Iron and Steel.—Mr. J. B. Mackintosh [*] describes a modification of M. V. Tantin's method for determining phosphorus in iron and steel. The following is the outline of the steps to be followed:—

1. Solution in hydrochloric acid in a stream of oxygen or air, absorbing the escaping gases in permanganate acidified with sulphuric acid. 2. Heating the solution to boiling, stopping the passage of the oxygen current, and adding an excess of sulphurous acid solution, and continuing the boiling until the precipitated MnO_2 in the absorption flasks is redissolved. This boiling should last several minutes. 3. Disconnecting the junctions between the absorption flasks and solution flask and between the solution flask and the acid flask, and allowing to cool. 4. Mixing solutions, filtering out residue, which is placed, with filter paper, in a porcelain dish, oxidising with nitric acid and potassium chlorate, and evaporating to dryness. 5. Boiling the solution till the excess of sulphurous acid is expelled, adding a few cubic centimetres of permanganate to peroxidise a little of the iron, and precipitating basic acetates. Boiling the filtrate for other precipitates, to insure obtaining all the phosphoric anhydride present. 6. Dissolving these precipitates in hydrochloric acid, and adding to the solution of the residue in which the paper will now have been thoroughly

---

[†] *Transactions of the American Institute of Mining Engineers*, vol. xiv. pp. 385–395.

destroyed. 7. Evaporating to dryness for silica, and proceeding as usual with the molybdate precipitation.

The saving of time by this process is the greater, as the percentage to be determined is less. In calculating the percentage of phosphorus from the weight of the yellow precipitate, the factor 1·63 per cent. is assumed.

The Estimation of Phosphorus.—W. Kalmann * describes the following method for the determination of phosphorus. According to the percentage of phosphorus present, from 1 to 10 grammes of the pig iron or steel which is to be assayed, are mixed with from one to two times the quantity of a mixture of two parts of calcined magnesia and one part of fusion mixture (potassium-sodium carbonate). The whole is then heated in a platinum crucible for about one hour, stirring every ten minutes. On cooling, the powdery mass is extracted in the hot with a quantity of citric acid sufficient to cause the solution to remain acid even after being heated. Then filter and wash the precipitate with a 1 per cent. citric acid solution, until the filtrate ceases to become turbid when treated with ammonium chloride and ammonia.

Ammonium chloride is then added to the filtrate, and when this has been done one-fourth the volume of strong ammonia is stirred in, and the ammonium-magnesium phosphate separates out. When the whole of the phosphate has been precipitated, the supernatant liquor is carefully decanted from the precipitate, passing it through a filter. The precipitate is then redissolved in hydrochloric acid, and reprecipitated with ammonia; it is obtained in this manner in a largely crystalline form, and may be filtered in as short a time as one-half to one hour.

The author shows by examples that this method is of considerable accuracy.

The following modified molybdate method is proposed by M. A. von Reis,† and is stated to give rapid and accurate results:—Five grammes of the steel filings to be assayed are treated with 80 cubic centimetres of nitric acid of 1·2 specific gravity, and are kept at a temperature of about 100° C. for half an hour. Fifty cubic centimetres of a solution of ammonium nitrate—750 grammes of the salt in 1 litre water—and 10 cubic centimetres of ammonia of 0·91 specific gravity are then added, and the phosphorus is precipitated by the addition of 50 cubic centimetres of molybdate solution, shaking well, and allowing the whole to stand for an hour at a temperature of from 80° to 90° C. Filter, and then wash the precipitate with a solution of 150 grammes ammonium nitrate and 50 cubic centimetres nitric acid in 1 litre of water. Dissolve the washed precipitate in strong ammonia, add 10 cubic centimetres of ammonium chloride solution—1 to 10—and precipitate with magnesia mixture in the ordinary manner.

---

* *Monatshefte für Chemie*, vol. vi. pp. 818–820.

† *Repertorium der analytischen Chemie*, vol. v. pp. 381–389.

To avoid the loss of time necessitated by having to weigh the precipitate, the author has employed the following titration method, which is based on the fact that the molybdic acid reduced to the black oxide by zinc and acid, may be reoxidised to molybdic acid:—

One gramme of pig iron is dissolved in 30 cubic centimetres of nitric acid of 1·2 specific gravity in a large porcelain dish, or, if steel is being assayed, 10 grammes are dissolved in 100 cubic centimetres of the above acid in a beaker. The silica is separated by evaporation, the residue dissolved, and to the filtrate so obtained an excess of ammonia is added, and after this a slight excess of nitric acid. The whole is evaporated to about 50 cubic centimetres, and an equal volume of a solution of 1 kilogramme ammonium nitrate in 1 litre of water is added, and, if steel is being examined, also 20 cubic centimetres of strong ammonia. The solution is then raised to the boiling point and a sufficient quantity of ammonium molybdate solution is added. It is allowed to stand for two or three hours, and is then filtered and washed with ammonium nitrate solution until potassium sulphocyanide ceases to produce a coloration. The precipitate is dissolved in ammonia, and diluted to 200 cubic centimetres; 10 cubic centimetres of concentrated sulphuric acid are added—more if a yellow precipitate is formed—and then 3 to 4 grammes of granulated zinc, and the solution is allowed to stand in the hot for one hour, or for two if the solution remains red. The supernatant solution is decanted from the undissolved zinc, and this is then washed with water. Sulphuric acid is added to the molybdic solution, and it is titrated with a standard solution of permanganate, which may be standardised either with pure ammonium molybdate or with oxalic acid. If this latter be used 1 gramme of it is equivalent to 0·8381 gramme of molybdic acid.

To determine the percentage of phosphorus present from the amount of molybdic acid found, this latter must be divided by 51·1 both in the case of pig iron and of steel, if the yellow precipitate was produced in the hot, and by 46·45 if the solution was not heated during the precipitation of the phospho-molybdate, as this was found to have the formula $(NH_4)_3PO_4 \cdot 10MoO_3$ if the solution was allowed to stand without heating, and $(NH_4)_3PO_4 \cdot 11 MoO_3$ if it was heated for an hour at a temperature of 80°–90° C.

The Estimation of Manganese.—Mr. J. J. Barlow [*] recommends the precipitation of manganese by hydrogen peroxide. The precipitated hydrate settles rapidly, is easily filtered, and is insoluble in ammonia, or ammonia salts. It is very close-grained, and if dried on a filter can be easily detached. The precipitation cannot be effected in the presence of iron, aluminium, or chromium. The other metals of the manganese group are not precipitated by the hydrogen peroxide. On the addition of the peroxide to a solution containing iron, aluminium, chromium, and manganese, the manganese is precipitated last.

Dr. C. G. Müller [†] recommends the use of the following process:—About 2 grammes of the substance to be assayed are dissolved in 16 cubic centimetres of hydrochloric acid and 5 cubic centimetres of nitric acid. The solution is diluted by the addition of 430 cubic centimetres of cold water, ammonium carbonate added in slight excess, and the iron precipitate formed redissolved with about 10 drops of hydrochloric acid. The solution is then boiled, and 1 cubic centimetre of glacial acetic acid and 5 cubic centimetres of a solution of ammonium acetate, obtained by the neutralisation of glacial acetic acid by ammonia, are added. After boiling for a short time the contents of the flask are diluted to 0·5 litre, and are then filtered through a dry filter, about three-fourths being filtered through. The filtered solution, the temperature of which is about 80° C., is charged into a broad-mouthed beaker, and 5 cubic centimetres of a solution containing 2·5 to 3 per cent. of a solution of hydrogen peroxide and an excess of ammonia are added, stirring well, the manganese being immediately precipitated. The solution is then boiled for half a minute and filtered, the filtration proceeding very rapidly on account of the character of the precipitate, which is very easy to remove from the sides of the beaker. The precipitate, after washing, is burnt in a platinum crucible, the whole assay requiring about 45 to 50 minutes.

If nickel or cobalt is present in the filtrate after precipitation of the iron by the acetate, a few drops of ammonium sulphide and the same quantity of glacial acetic acid are added, and the sulphides of cobalt and nickel allowed to settle out.

---

[*] *Chemical News*, vol. liii. pp. 41–42.

[†] *Stahl und Eisen*, vol. vi. p. 101.

C. Reinhardt * is of opinion that if it is desired to determine manganese by ordinary analysis, the method proposed by Wolff is the best, as it gives exceedingly good results, owing to the precipitation being complete and the precipitate easy to filter and wash; and he shows that a second precipitation is sufficient to render the precipitate pure, even in the presence of large quantities of magnesia. The author has not obtained good results with Holthof's method as originally proposed, but the results were accurate when using the following modification:—

The hydrochloric solution of the ore is placed in a 1-litre Erlenmeyer flask, neutralised with ammonium carbonate; slightly acid ammonium acetate added; boiled and precipitated. The acetate precipitate after filtration is dissolved off the filter by hydrochloric acid, neutralised and precipitated as before, and then passed through the same filter. This operation is repeated twice.

The filtrates are combined, heated, and, when warm, a solution of bromine in hydrochloric acid is added until a red colour appears; 60 to 100 cubic centimetres of 20 per cent. ammonia are then added rapidly; the whole is shaken well, and for half an hour ammoniacal air (the wash-water contains an ammoniacal solution of calcium chloride) is passed through. The solution, which, if but small quantities of manganese are present, will be of a yellow colour, will become perfectly clear after the passage of the ammoniacal air, as the precipitate, to the solution of which the yellow colour was due, falls in a flocculent form. No manganese remains in the solution.

Reinhardt has examined the volumetric method proposed by N. Wolff,† but the results he obtained were not very favourable; and he is of opinion that this was due to the manganese dioxide precipitated always containing some manganous oxide.

The author has also examined a method proposed by Belani, in which, as in the Pattinson method, the manganese is precipitated as dioxide, in the presence of an excess of iron in the precipitate, and is then determined by a standard solution of ferrous sulphate. The manganese is precipitated from the acetate filtrate by bromine water in the usual manner. The precipitate is dissolved in the standard ferrous sulphate

---

* *Stahl und Eisen*, vol. v. pp. 782–788.

† *Journal of the Iron and Steel Institute*, 1885, p. 301.

solution, and the excess of ferrous salt titrated with permanganate. The exact method of procedure is as follows :—

Two grammes of pig iron are dissolved in a little dilute nitric acid in a 1-litre flask. On solution it is diluted to about one-third of a litre, nearly neutralised with sodium carbonate, 2 grammes of sodium acetate and a few drops of acetic acid added, and then heated to boiling. It is then diluted to 1 litre and filtered through a large folded filter into a one-half litre flask, in which 150 cubic centimetres of the solution and precipitate well mixed together (or more if much manganese was present) have been placed. When the filtrate has reached the one-half litre mark, the flask is removed. In this manner the greater quantity of the iron precipitate has been removed. The contents of the smaller flask are then returned to the larger one, after its contents have been removed and it has been washed with water. Some strong bromine-water is added, the whole being then heated to boiling, and boiled rapidly for two minutes after the precipitation. It is then filtered hot, and washed with boiling water until the bromine has been got rid of. The filter and its precipitate are then treated with 50 cubic centimetres of a solution of 20 grammes of ferrous sulphate in 150 grammes of sulphuric acid and 800 grammes of water. A few cubic centimetres of sulphuric acid are added, and the solution rapidly becomes clear. It is then diluted to three times its original volume, and is titrated with a standard solution of permanganate. The time occupied in an assay by this method is about 1½ hour; spiegeleisen takes somewhat longer.

The author has compared this method with the analytical one of Fresenius (solution of the dioxide, and precipitation as manganous carbonate), and the differences in the results by the two methods were very slight; he considers the method far superior to that of Vollhard.

C. Reinhardt * has also instituted a series of comparative examinations of the Wolff, Belani, Hampe,† and Meineke methods for the estimation of manganese.

The Wolff volumetric method, he has found, always gives results which are considerably too low, besides which the titration by permanganate in a brown emulsion is by no means without difficulty.

The Belani method has numerous defects, which are pointed out by the author, and he at first endeavoured to neutralise the solution with zinc oxide instead of with sodium carbonate, followed by a precipitation of the iron by sodium acetate, in the hope that the zinc oxide not

---

* *Stahl und Eisen*, vol. vi. pp. 150–166.

† *Journal of the Iron and Steel Institute*, 1885, p. 652.

precipitating the iron, any loss of manganese in the acetate precipitate would be avoided, and that, besides this, the zinc salts which are formed would tend to cause the manganese precipitate produced on the addition of bromine to be free from manganous oxide. This proved, however, not to be the case, and he has consequently adopted the following modified method:—

One-half to 2 grammes of the ore (for pig irons poor in manganese the Belani method is not suitable) are dissolved in the hot in 25 to 40 cubic centimetres of hydrochloric acid of 1·19 specific gravity; strong nitric acid is then added in the proportion of 10 cubic centimetres for each gramme of the ore treated, and the solution is boiled until chlorine has ceased to be evolved. The solution is then neutralised by zinc oxide, which is added from time to time, stirring well, until the ferric hydrate suddenly gelatinises, or, if very little iron be present, until the solution becomes slightly turbid. The whole is then diluted to one-half litre, and well shaken; it is then filtered through a dry filter, and a definite proportion—about 250 cubic centimetres—of the filtrate is placed in a large flask, and 10 to 20 cubic centimetres of basic ferric sulphate and 20 to 35 of bromine water are added to it. Sufficient ferric sulphate is added to cause the percentage of iron present to equal that of the manganese. The solution is then heated to boiling, and boiled until the odour of bromine has disappeared. The precipitate is allowed to settle, and is then separated by filtration. The filter and its contents are placed in a beaker and treated with a definite quantity—50 to 100 cubic centimetres—of a solution produced by dissolving 16 grammes of oxalic acid crystals in 500 cubic centimetres of water, to which are then added 400 cubic centimetres of concentrated sulphuric acid, and the whole diluted to 2·5 litres. The complete reduction is shown by the solution becoming of a clear yellow colour. It is then titrated with permanganate.

A modified method for the assay of pig iron is also discussed, as is also Hampe's method. This the author considers to be of great accuracy, and he has introduced certain modifications to admit of its application not only to pig iron and steel, but also to iron ores. One such modified method—the one he considers most accurate—the author describes as follows:—One-half to 2 grammes of the ore are dissolved in a 400 cubic centimetre Erlenmeyer flask in 20 to 40 cubic centimetres of hydrochloric acid of 1·19 specific gravity. When the solution is completed fifty glass beads, each about 3 millimetres in diameter, 2 millimetres thick, and pierced with a 1-millimetre hole, are added, as are 25 cubic centimetres of nitric acid of 1·4 specific gravity, and the solution is then boiled for from five to ten minutes. When this period has elapsed another 25 cubic centimetres of the nitric acid are added, and the boiling is repeated for another ten minutes. This addition of nitric acid and boiling is then again repeated, and the precipitation with potassium chlorate commenced, each addition of potassium chlorate—about 2 grammes at a time—being followed by five minutes boiling. When the precipitation is completed the solution is diluted to 200 cubic centimetres by the addition of water at a temperature of from 50° to 60° C., as boiling water will cause the percentage of manganese found to be too low. The filtered precipitate is washed until no more chlorine can be detected in the wash-water, the precipitate is treated with a standard solution of oxalic acid, and the excess of the oxalic acid titrated back with permanganate.

The method proposed by Meineke consists in treating the solution of manganous oxide, neutralised with a slight excess of zinc oxide, by adding it to a measured quantity of a permanganate solution containing 25 to 30 grammes of zinc sulphate. The excess of permanganate is then titrated back with antimony chloride. The method, which is described in detail, is capable of considerable accuracy, but the manipulation requires great care.

The Estimation of Sulphur in Iron.—A colorimetric method for this purpose is described by J. Wiborgh.* It consists in dissolving the iron, in which the sulphur is to be determined, by sulphuric or hydrochloric acid. The gases escaping during the solution of the iron are passed through a material soaked with the salt of a metal the sulphide of which, produced by the action of the sulphuretted hydrogen formed during the solution of the iron, colours the cloth. The strength of the coloration determines the percentage of sulphur present in the metal assayed. For this purpose the author originally employed filter paper, but he found that in practice cloth was much better suited for the purpose, as the paper after becoming moist by the action of the steam was too liable to tear. The author now employs fine white calico. This he colours with a solution of a cadmium salt. Of the salts of cadmium, the nitrate gives a very deep and beautiful colour, somewhat approaching orange-yellow; the sulphate produces a lighter colour, with a yellow-brown tint; the chloride and the acetate give each a light yellow, and it is the last-mentioned salt that the author prefers to employ. The solution used to colour the cloth contains 5 grammes of the crystallised acetate in 100 cubic centimetres of water.

---

* *Jern-kontorets Annaler*, vol. xli. pp. 105–119.

The apparatus used in the test—a drawing of which is given, together with a coloured diagram of the colour scale employed—consists simply of a wide-mouthed tube, the narrow end of which is inserted through the cork of the flask in which the solution is effected. At the mouth of the tube there is an arrangement by which the cloth may be stretched tightly across.

The actual method of carrying out the test is as follows:—The flask in which the iron is to be dissolved is half filled with water and placed on a sand-bath. The metal filings to be assayed are introduced when the water is at a gentle boil. To do this they are placed in a short tube, to the upper end of which a piece of platinum wire is attached; the whole being introduced into the flask, the wire, resting against the sides, causes the tube to remain in an upright position. The prepared cloth is then stretched across the tube, and the stopper being introduced into the mouth of the flask, acid is added, about 10 cubic centimetres of dilute sulphuric acid being used for 0·4 gramme of iron.

When the whole of the iron has been dissolved, the solution is allowed to boil for about ten minutes longer, the cloth removed, allowed to dry upon filter paper, and the sulphur determined by comparing the colour of the cloth with the scale adopted.

The operation is very rapid and accurate. Copper and arsenic are without influence.

Silver-Foil Sulphur Test.—According to L. Rinman,* serious errors may occur in the Eggertz silver-foil test for sulphur, if the precaution is not first taken of converting the pig iron into grey or graphitic iron. Some years ago the author made dry assays of an iron ore containing lime and manganese and finely disseminated magnetic pyrites. With quartz this ore gave a clear, almost colourless glass and pig iron with a white fracture. Mixed with 50 per cent. of a quartzose oxidised ore free from sulphur, the same ore gave a graphitic pig iron. In this assay the proportion of sulphur should have been but half as great as in the first. But the latter gave only a brass colour on silver-foil, whilst the second assay coloured the foil blue. Quite recently the author found only 0·03 per cent. of sulphur in a pig iron with a mixed white and grey fracture, whilst the iron remelted in a charcoal-lined crucible gave on silver-foil 0·075 per cent. of sulphur. Consequently, the remelting of the iron assay is the simplest and safest method of obtaining a trustworthy result.

---

* *Jern-kontorets Annaler*, vol. xl. p. 362.

The Estimation of Chromium.—H. Vignal * dissolves 0·5 gramme of the alloy in a mixture of 15 cubic centimetres of water and 5 of sulphuric acid. When the solution is complete 25 to 30 cubic centimetres of nitric acid are added, and the solution is again boiled for a moment to complete the peroxidation of the iron and to expel nitrous vapours. Potassium permanganate is added in crystals to the hot solution until, the chromium having been oxidised to chromic acid, the solution becomes turbid owing to the formation of oxides of manganese, which, on boiling the solution, collect as precipitated peroxide. The solution is then filtered through asbestos, and titrated with a standard ferrous solution, a little sulphuric acid being added, the excess of ferrous salt being titrated back with permanganate. An approximate estimation of the chromium is obtained direct by using a standard concentrated permanganate solution, instead of crystals of the salt, in the oxidation of the chromium. A chromium ore is assayed by fusing one part of it in a platinum crucible with one part sodium carbonate and one part potassium nitrate, both finely ground. The melted mass is cooled, and then dissolved in water. The soluble portion contains chromium in the form of chromic acid, and this is determined by a ferrous solution. The insoluble portion is dissolved in hydrochloric acid, and is then treated like an ordinary iron ore.

The permanganate solution used for the oxidation of the chromium to chromic acid should have a strength of about 20 grammes of the salt to the litre.

Chromium-Iron Alloys.—According to L. Schneider,† the rich chromium-iron alloys which are occasionally employed in the manufacture of exceptionally hard varieties of steel, exhibit the formation of crystalline alloys in the blowholes and on the surface of the main mass, and these increase proportionately with the percentage of chromium. The heterogeneity of these alloys became evident on attacking the mass with hydrochloric acid.

An alloy containing about 50 per cent. of chromium on being attacked by hydrochloric acid, dissolved in part, leaving a residue which was not attacked by the acid, the reason being that an oily hydrocarbon had formed, which coated the alloy and prevented contact. On being freed from the oil a further portion of the alloy was dissolved, and it was found possible to dissolve the whole of it by repeating the attacks. The last portion which passed into solution consisted of very small needle-shaped crystals, and it was found possible to separate these from the main mass of the alloy by attacking it with cupric chloride, when all the chromium remains in the residue, the greater part of the iron passing into solution. On analysis this residue was found to consist of—

---

* *Bulletin de la Société Chimique de Paris*, vol. xlv. p. 171.

† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxiii. p. 297.

Chromium.	Iron.	Carbon.	Total.
66·2	24·9	8·5	99·6

It was tin-white, very hard and non-magnetic, and had a specific gravity of 6·97 at 20° C.

The method adopted for the analysis was the following:—One gramme of the alloy was dissolved in moderately concentrated sulphuric acid, evaporated to dryness, and the sulphuric acid driven off; taken up, and, no silica being present, diluted without filtration to 0·5 litre, partially neutralised with sodium carbonate, the chromium oxidised by bromine and the iron precipitated by ammonia. The boiling chromium solution, slightly acidulated with sulphuric acid, was gradually oxidised by potassium permanganate until the red colour appeared, the excess of permanganate destroyed by manganous sulphate, filtered, and the chromium determined in the ordinary manner, with the double iron-sodium sulphate and permanganate.

The only method for the estimation of the carbon which it was found possible to use was that of mixing the finely powdered alloy with litharge and burning in a current of oxygen, dissolving in nitric acid, and recombustion of the residue.

Determination of Titanium in Iron and Steel.—Mr. H. L. Wells* advocates the following colorimetric method for the determination of small quantities of titanium in iron and steel.

One gramme of the metal to be tested is dissolved in nitric acid; 10 cubic centimetres of concentrated sulphuric acid are added; the nitric acid is removed by evaporation; the sulphuric acid is strongly heated to insure the solution of all the titanium; the sulphates are dissolved in water; and the solution is filtered and diluted to 100 cubic centimetres in a small beaker. In a second beaker is placed a quantity of a solution of ferric sulphate in sulphuric acid containing the same amount of iron as the metal analysed, and this is diluted, if necessary, to 100 cubic centimetres. The colours of the solutions in the two beakers should now be identical. About 5 cubic centimetres of hydrogen peroxide are added to the second beaker, and should produce no change of colour. Then the same amount of hydrogen peroxide is added to the first solution; if this deepens the colour, titanium is indicated. The amount of titanium is determined by adding a standard solution of titanium dioxide in sulphuric acid from a burette to the blank until the colour corresponds. The reaction is extremely delicate, as little as 0·0001 gramme of titanium showing in the presence of 1 gramme of iron as ferric sulphate.

---

* Paper read at the Pittsburg meeting of the American Institute of Mining Engineers, February, 1886.—*Transactions*, vol. xiv. pp. 763–766.

II.—*ANALYSIS OF IRON ORES AND SLAGS.*

The Estimation of Iron by Electrolysis.—T. Moore * adds to the distinctly acid solution of the ferric sulphate or chloride a solution of glacial phosphoric acid until the yellow colour completely disappears. A large excess of ammonic carbonate is then added, and the solution, raised to a temperature of 70° C., is electrolysed by a current of sufficient strength to produce 1200 cubic centimetres of mixed gases per hour. The iron is rapidly and completely deposited.

Reduction of Ferric Solutions by the Use of Amalgamated Zinc and Platinum Foil.—In the determination of iron in sulphuric acid solutions by titration with potassium permanganate, amalgamated zinc and platinum foil are generally employed to reduce the iron to the ferrous state. Their use is attended with two difficulties—the amalgamation of the platinum and the transferring the solution from the reducing-bottle to the beaker. Mr. A. L. Beebe † overcomes these difficulties by a simple modification of the usual method. A strip of thin platinum foil, about 1 inch square, is perforated with pin-holes over its entire surface. It is then bent, and its opposite corners are connected by short pieces of platinum wire, so as to form a sort of basket. In this is placed a piece of amalgamated zinc, and the whole is suspended by a platinum or silver wire in the bottle containing the solution to be reduced. Another strip of platinum foil, 1·5 by 2·5 inches, is then dropped into the bottle, in such a way as to lean against the wire without coming into contact with the basket and zinc. Galvanic action at once commences. The foil never becomes amalgamated, as it comes only in indirect contact with the zinc. When the reduction is complete the platinum basket is removed, washed in the titrating beaker, and laid aside, all danger of fracture being thus avoided.

---

* *Chemical News*, vol. liii. p. 209.

† Paper read at the Pittsburg meeting of the American Institute of Mining Engineers, February, 1886.—*Transactions*, vol. xiv. p. 766.

Estimation of Phosphoric Acid in Basic Bessemer Slag.—J. Klein,[*] having compared various methods for the estimation of phosphoric acid in basic slags, considers the following to be the best:—2·5 grammes of slag are fused with from 5 to 7 grammes of a mixture of four parts by weight of sodium potassium carbonate and one of potassium chlorate. The mixture is first gently heated in a platinum crucible over a Bunsen burner, and then the mixture is fused. The fused mass is extracted in a beaker with 50 cubic centimetres of hydrochloric acid, and diluted to 250 cubic centimetres, 100 of which are evaporated for the determination of the silica, the residue so obtained is extracted in the ordinary manner, and the phosphoric acid determined by ammonium molybdate.

Titration of Phosphoric and Arsenic Acids.—A. Joly[†] adds a few drops of phthalein to the acid solution, and then a standard solution of baryta, until a gelatinous precipitate forms. This is a tri-barium salt which decomposes when in contact with the acid solution, either voluntarily or on stirring, forming a crystalline precipitate of a bi-barium salt. The baryta solution being added carefully, a fresh gelatinous precipitate is formed, which is again rapidly decomposed as above. The process is completed when a drop of the baryta solution produces an intense and lasting red coloration.

The conversion of the gelatinous precipitate into the crystalline salt takes place very rapidly in the case of the titration of arsenic acid.

Analysis of Manganese Ore.—According to P. Charpentier,[‡] the manganese peroxide is heated with hydrochloric acid, and the chlorine evolved passed into a solution of ferrous sulphate. The solution is then mixed with a small quantity of ammonium chloride and potassium sulphocyanate, and a standard solution of potassium hydroxide run in until the red colour disappears.

---

[*] *Chemiker Zeitung*, vol. x. p. 341.

[†] *Comptes rendus de l'Académie des Sciences*, vol. cii. p. 316.

[‡] *Ibid.*, vol. cii. pp. 316-318.

A second method is to distil the peroxide with hydrochloric acid, and to pass the chlorine evolved into an aqueous solution of silver nitrate. A drop of ferric nitrate is then added, and the solution titrated with potassium solphocyanate.

III.—*ANALYSIS OF FUEL.*

The Estimation of Nitrogen in Coal and Coke.—S. Schmitz* has frequently used both the Dumas and the Varrentrapp-Will methods for the estimation of nitrogen in connection with assays of coal and of coke; and with regard to Dumas' method he points out that it is difficult to manipulate, as neither the coal nor the coke is completely burnt in a current of carbonic anhydride, even when treated for four or five hours at a very high temperature. The carbonic anhydride, too, is exceedingly difficult to obtain altogether free from air, and the tension in the glass tube is so great that it may easily either burst or blow out.

The Varrentrapp-Will method has up to the present alone been used for the estimation of nitrogen in coal and in coke; but the author, who has investigated the process, has found that the results are too low in the case of coal, and that in the case of coke they are altogether unreliable. A coal which was found to contain, by a method about to be described, 1·77 per cent. of nitrogen, gave after combustion with soda-lime for a period of three hours 1·61 per cent. of nitrogen, and some unburnt coal was afterwards found on dissolving the soda-lime. This result was obtained when using 0·35 gramme of the coal, but with twice this quantity successive assays gave the following percentage of nitrogen:—1·16, 1·20, and 0·95. The unburnt residues were afterwards treated by the modified method adopted by the author, and in the case of the 1·16 per cent. result 0·54 per cent. more nitrogen was obtained, raising the total to 1·70 per cent.; in the case of the assay which showed 0·95 per cent. of nitrogen 0·78 more was found, raising the total percentage to 1·73. Similar results were obtained in the case of some assays of coke.

---

* *Stahl und Eisen*, vol. vi. p. 47.

The method proposed by Kjeldahl in 1883, and since modified by Stutzer-Reitmair, has been further modified by the author in his attempts to employ it for the determination of nitrogen in coal and in coke, and the following is the method he now adopts:—

From 0·8 to 1 gramme of coal, or 0·5 to 0·7 gramme of coke, very finely powdered, is placed in a one-quarter litre flask, formed of well-cooled potash glass, and 1 gramme of finely powdered oxide of mercury and 20 cubic centimetres of concentrated sulphuric acid are added, the whole being then kept in rapid boil for from two to three hours. All varieties of coal, and even anthracite, will be in solution at the termination of this period. The contents of the flask are allowed to cool, and are then poured into an Erlenmeyer flask containing some water, and kept well cooled; after this has been done, 120 to 140 grammes of a solution of caustic soda of 30° to 32° B. are added, as are also 35 cubic centimetres of a solution of yellow sodium sulphide, containing about 40 grammes of Na_2S to the litre. Finally, a small piece of zinc is charged in, to prevent jumping, and then boiled in a flask for about twenty minutes. An arrangement for collecting any drops of liquid that may be carried forward is introduced between the flask and the cooler. The cooler dips into a flask containing, in the case of coal, 30 cubic centimetres, and for coke, 20 cubic centimetres, of a standard sulphuric acid solution, and this is titrated back by a standard baryta solution, rosolic acid being used as an indicator.

The following are the results of some assays by this method:—

	Nitrogen, Per cent.
Cannel coal from the Wilhelmine Victoria Colliery	1·78 1·76
Caking coal from the Bonifacius Colliery	1·74 1·61
Anthracite from Piesberg, near Osnabrück	0·52 0·51

Coke is treated in the same way as coal, in that it is treated with the same quantities of sulphuric acid and mercuric oxide, but at the end of one hour 1 gramme of the latter is added little by little, and then, in a similar manner, 2 grammes of finely powdered potassium permanganate are added to the solution when at a rapid boil. It is necessary to shake the flask frequently, so as to wash down the particles of coke which are continually rising and adhering to the sides of the flask. As two grammes of mercuric oxide have been added, it will of course be necessary to employ twice the quantity of sodium sulphide solution; the distillation and titration are effected as before.

Results of assays of coke were as follows, the coke being from the coal obtained at the General Colliery:—

Nitrogen, per cent. . . . . 1·03, 1·18, and 1·24.

In the case of "patent coke," however, the author has not as yet been able to obtain perfectly satisfactory results by the above method.

IV.—*GAS ANALYSIS.*

Gas Analysis.—In his work on the "Chemistry of Iron," the late Mr. M. Troilius * gives the following convenient method for the complete volumetric analysis of gases as they occur in iron and steel manufacture.

The gases to be determined are carbonic anhydride, oxygen, ethylene, carbonic oxide, hydrogen, and marsh-gas. The nitrogen is taken by difference. Besides these gases, the mixture may contain small quantities of sulphurous anhydride, sulphuretted hydrogen, &c. The gas mixture may also contain a quantity of steam when coming hot from the furnaces. This may be estimated by passing a quantity of the hot gas through a weighed chloride-of-calcium-tube, and measuring the volume of gas thus passed through. Sulphuretted hydrogen and sulphurous anhydride cannot be determined over water. In this case mercury tubes must be used. A solution of 3 grammes of iodine with 4·5 grammes of potassium iodide in 50 cubic centimetres of water can be used for absorbing these gases. The sulphurous anhydride is then oxidised to sulphuric acid, and the sulphuretted hydrogen is converted into hydriodic acid, with separation of sulphur; the iodine solution thus losing its brown colour.

For determining the ordinary ingredients, a sample of gas is taken into a burette of 100 cubic centimetres capacity, graduated into 0·1 cubic centimetres; the burette being previously filled with water. The volume of the gas drawn in is read off by closing the stop-cock at the lower end of the burette. It is well to have the gas a little compressed, so that 1 cubic centimetre or so will bubble out through the water in the funnel at the top of the burette. The volume of gas should be read off by the lower part of the water surface. The temperature is noted, and correction is made for the amount of aqueous vapour corresponding to the temperature. The temperature should be observed throughout the subsequent operations, as the gas expands according to the formula $v\ (1 + 0{\cdot}004\ t^{\circ})$, or about 0·4 cubic centimetre for every degree Centigrade.

---

* *Notes on the Chemistry of Iron.* New York: John Wiley & Sons, 1886.

The *carbonic anhydride* must first be determined. For its removal is used a solution of 16 grammes of potassium hydrate in 100 cubic centimetres of water. Four or five cubic centimetres of this solution absorb 100 cubic centimetres of carbonic anhydride. Draw out a few cubic centimetres of water, and allow a few cubic centimetres of the potassium hydrate solution to flow into the burette from the funnel. All the carbonic anhydride is absorbed when the alkaline liquid flows down slowly along the sides of the burette. The potassium hydrate is then carefully washed out, and the remaining volume of gas is then read off.

The absorption of the *oxygen* is effected by means of potassium pyrogallate. Twenty grammes of pyrogallic acid are dissolved in 100 cubic centimetres of air-free water. This solution is mixed, immediately before use, with its equal volume of potassium hydrate solution. Two cubic centimetres of this solution absorb the oxygen in 100 cubic centimetres of air.

Ethylene decomposes at a high heat into carbon and marsh-gas, and does not generally occur in blast-furnace gas, nor in producer gases from coke. Producer gases from bituminous fuel, however, may contain as much as 2 per cent. Fuming sulphuric acid, as well as bromine, absorb ethylene. Bromine is the more convenient reagent to use. Caution must be observed, as the bromine vapour has a great tension. One-hundredth of a gramme of bromine absorbs about 1 cubic centimetre of ethylene, forming ethyl-bromide. Water shaken up with bromine contains 0·02 to 0·03 grammes of bromine per cubic centimetre. A very small amount of bromine water is consequently required. The ethyl-bromide appears in oily drops on the sides of the burette when ethylene is present.

The *carbonic oxide* is absorbed by means of a solution of 15 grammes of red oxide of copper in 100 cubic centimetres of hydrochloric acid (sp. gr. 1·19). The solution is prepared by adding the Cu_2O to the hydrochloric acid at a temperature of 75°, and allowing a little paraffin to melt on the surface to prevent oxidation. One cubic centimetre of the fresh sub-chloride of copper solution absorbs about 20 cubic centimetres of carbonic oxide.

After removing the gases mentioned above, for the determination of *hydrogen* and *marsh-gas*, about 20 cubic centimetres of pure oxygen are taken into the burette, the gas having been previously transferred to another burette. The gas is then brought back, and the total volume read off. As a safeguard against explosions, the rule may be observed, that the sum of the volumes of the gases taking part in the combustion must not exceed one-half of the total volume of gases in the burette. A platinum tube connects the two burettes. This tube has an internal diameter of 0·5 millimetre, and is twisted into a single coil and provided with small cylinders of German silver at the ends; to these cylinders indiarubber tubing can be securely attached. The coil is now heated to redness by means of a small Bunsen burner, whilst the gas is passed from one burette to the other and back again. Complete combustion of hydrogen and marsh-gas then takes place in the tube. Water-vapour, which condenses, and carbonic anhydride are formed, one volume of hydrogen giving one volume of water, and one volume of marsh-gas giving two volumes of water and one of carbonic anhydride. The actual number of cubic centimetres representing the *free* hydrogen in the original gas volume is obtained from the formula—

$$\text{Hydrogen} = \tfrac{2}{3}\,[M - 2\,G],$$

M being the *total* diminution of volume after combustion, and G the volume of carbonic anhydride from the marsh-gas. This carbonic anhydride is determined as previously described, giving the volume of marsh-gas direct.

STATISTICS.

CONTENTS.

		PAGE
I.	United Kingdom	407
II.	Austria-Hungary	410
III.	Belgium	412
IV.	Borneo	414
V.	Canada	414
VI.	China	414
VII.	France	415
VIII.	Germany	419
IX.	India	420
X.	Italy	421
XI.	Portugal	421
XII.	Russia	421
XIII.	Spain	422
XIV.	Sweden	424
XV.	United States	425

I.—*UNITED KINGDOM.*

Mineral Statistics.—According to the preliminary returns of Her Majesty's Inspectors of Mines, the production of coal, fireclay, and ironstone in Great Britain and Ireland during the year 1885 was as follows :—

District.	Persons Employed in and about the Mines.	Tons of Mineral Wrought.			Number of Mines.
		Coal.	Fireclay.	Ironstone.*	
Northumberland, Cumberland, and North Durham	53,011	16,427,529	320,939	773	203
South Durham, Westmoreland, and North Riding of Yorkshire	55,771	20,402,479	221,013	...	194
Cleveland (ironstone)	6,713	...	...	5,932,244	36
North and East Lancashire	31,640	9,738,674	96,696	...	287
Ireland	860	109,035	900	...	27
West Lancashire and North Wales	41,565	13,176,944	59,047	2,594	225
Yorkshire	63,562	18,497,778	200,722	126,596	395
Lincolnshire (ironstone)	115	...	...	81,521	10
Derbyshire, Leicestershire, Nottinghamshire, and Warwickshire	55,163	16,963,684	77,122	29,386	355
North Stafford, Cheshire, and Shropshire	21,889	6,324,600	66,000	1,920,920	225
South Staffordshire and Worcestershire	23,137	9,862,497	185,632	117,726	365
Monmouth, Somerset, and parts of Glamorgan and Breconshire	35,659	9,352,072	88,277	126,037	294
South Wales	61,617	17,207,540	106,920	35,656	305
Scotland, East	46,022	14,905,620	192,826	504,023	323
Scotland, West	23,908	6,382,966	262,420	1,331,136	244
Totals and averages in 1885	520,632	159,351,418	1,878,514	10,108,612	3,488
Ditto in the preceding year	520,376	160,757,779	2,053,927	10,412,443	3,554

* Exclusive of ironstone worked at open works.

During the past year the aggregate number of persons employed in and about the whole of the mines in the United Kingdom of Great Britain and Ireland amounted to 561,676. Of these, 520,632 were employed under the Coal Mines Regulation Act, and 41,044 under the Metalliferous Mines Regulation Act. The total number of fatal accidents was 866, and the total number of deaths occasioned thereby 1214; showing a decrease, compared with the totals for the preceding year, of 51 in the number of fatal accidents, and an increase of 216 in the number of lives lost. There was one fatal accident to every 648 persons employed, and one death by accident to every 462 persons employed. The average for the ten years, 1874 to 1883, is one fatal accident to every 594 persons employed, and one death by accident to every 458 persons employed. The proportion of fatal accidents to the number of persons employed is, therefore, lower than the average of the last ten years, and the death-rate is also lower. Of the 520,632 persons employed in and about the mines under the Coal Mines Act, 424,191 were employed under ground, and 96,441 (of whom 4303 were females) above ground; thus showing, as compared with the preceding year, an increase of 256 persons. Of the deaths in coal-mines, 341 were from fire-damp explosions, 439 by roof and sides falling, 76 by shaft accidents, 219 by miscellaneous underground accidents, and 75 by miscellaneous surface accidents. The fatal accidents in 1885 in and about the mines classed under the Metalliferous Mines Regulation Act amounted to 59, and the deaths to 64. Of these, 58 deaths occurred under ground, and 6 above ground. During the year, 41,044 persons were employed in and about the mines of Great Britain and Ireland under this Act, being a decrease of 3076 persons compared with the preceding year. Of those employed in Great Britain, 24,393 were under ground, and 15,861 above ground, and in Ireland 509 under ground, and 281 above ground. There was one fatal accident to every 695 persons employed in and about the mines, and one death to every 641 persons employed. In the preceding year there was the smaller proportion of one accident to 817 persons, and one death to 787 persons.

Iron Trade Statistics.—The following is a summary of the principal statistics given in the ninth annual Statistical Report of the Secretary of the British Iron Trade Association:—

Description.	1883.	1884.	1885.
	Tons.	Tons.	Tons.
Production of pig iron	8,490,224	7,528,966	7,250,657
Stocks of pig iron at 31st December . .	1,698,978	1,809,467	2,352,169
Home consumption of pig iron . . .	8,449,368	7,383,475	6,707,955
Production of hæmatite iron . . .	3,287,000	2,770,000	2,560,000
Production of spiegeleisen	208,445	166,828	141,497
Production of puddled bar	2,730,504	2,240,535	1,911,125
Production of Bessemer steel ingots . .	1,553,380	1,299,676	1,304,129
Production of Bessemer steel rails . .	1,097,174	784,968	706,583
Production of open-hearth steel . . .	455,500	475,250	583,918
Production of coal in United Kingdom .	163,737,327	160,757,000	159,351,000
Shipbuilding, tonnage constructed . .	1,329,603	723,016	540,371
Shipbuilding in course of construction at end of year	729,446	373,808	318,567
Exports of pig iron from United Kingdom .	1,564,137	1,269,677	960,000
Exports of railroad iron	971,662	729,236	711,000
Total exports of iron and steel . . .	4,044,273	3,496,352	3,128,401

Loss of Life in Mines.—Mr. W. J. Bird * gives tables of the loss of life from 1851 to 1884, showing that the mortality in coal-mines has decreased, as in the total of accidents from all causes the mortality is 2·88 per 1000 on the whole period, and it has fallen from 3·54 per 1000 before the Coal Mines Regulation Act to 2·19 per 1000 since—a reduction of 34 per cent. The mortality in the North of England, Derby, and Nottinghamshire is considerably below the average; in Yorkshire and West Scotland slightly under the average; and above the average in South Staffordshire and Worcestershire; more so in North and East Lancashire; and is highest in South Wales.

Exports and Imports.—According to the Board of Trade Returns, the exports of iron and steel, and coal from the United Kingdom during 1885 and 1884 were as follows :—

Description.	1885.	1884.
	Tons.	Tons.
Pig iron	960,160	1,269,576
Iron, bar, angle, bolt, and rod	264,272	296,489
Railroad of all sorts	711,415	728,540
Wire (exclusive of telegraph wire)	55,086	52,968
Hoops, sheets, boiler and armour plates . .	331,471	348,298
Tin plates and sheets	297,728	288,614
Cast and wrought manufactured iron (exclusive of ordnance . . . . }	349,978	376,367
Old iron, for re-manufacture	84,945	68,141
Steel, unwrought	60,466	56,934
Manufactures of steel, or of iron and steel combined	12,880	11,064
Totals	3,128,401	3,496,991
Coal and coke	23,767,275	23,350,230

---

* *Transactions of the North of England Institute of Mining Engineers*, vol. xxxv. pp. 71–78.

The imports of iron ore, iron, and steel into the United Kingdom during 1885 and 1884 were as follows :—

Description.	1885.	1884.
	Tons.	Tons.
Iron ore	2,817,597	2,728,672
Iron, bar, angle, bolt, and rod	122,819	115,099
Steel, unwrought	6,754	11,232

The destinations of the iron and steel exported from the United Kingdom were as follows :—

Countries.	Total Exports, 1885.	Total Exports, 1884.
	Tons	Tons.
United States	397,613	454,755
British North America	178,078	172,290
India	453,642	337,780
Australia	333,520	331,819
British South Africa	25,225	22,313
Russia	119,733	200,532
Germany	231,716	341,713
Holland	199,283	243,916
Belgium	32,189	56,728
France	95,503	126,145
Italy	93,334	111,160
Turkey	8,319	15,135
Sweden and Norway	19,571	26,825
Spain and Canary Islands	19,881	42,000
Egypt	28,732	11,648
Mexico	884	4,314
Brazil	32,465	54,289
Peru	3,068	8,124
Chili	9,684	21,277
Argentine Republic	98,105	174,853
Destinations not specified	747,856	739,375
	3,128,401	3,496,991

II.—*AUSTRIA-HUNGARY.*

Production and Consumption of Pig Iron.—According to Professor F. Kupelweiser,* the production of pig iron in the Austro-Hungarian monarchy in 1884 was as follows :—

---

* *Zeitschrift des Oesterreichischen Ingenieur- und Architekten-Vereins*, vol. xxxviii. pp. 36-50.

District.	Charcoal Pig Iron.	Mineral Fuel Pig Iron.	Total Pig Iron.
	Tons.	Tons.	Tons.
South Austria	190,119	63,000	253,119
North Austria	29,935	256,567	286,502
Hungary	164,725	30,000	194,725
Totals . . .	384,779	349,567	734,346

In order to determine what the production and consumption of pig iron is per head of population, from the results of the census of 1869 and that of 1880, the population in 1884 may be estimated at 22,788,340 for Austria, and 15,855,252 for Hungary, giving a total for the monarchy of 38,643,592. The production per head of population in kilogrammes was as follows :—

District.	1869.	1880.	1884.
Austria	13·6	14·5	23·7
Hungary	8·2	9·1	12·2
Average	11·3	12·2	19·0

The consumption of pig iron in Austria is 28·8 kilogrammes per head of population.*

Ingot Iron and Steel.—At the present time in Austria-Hungary there are :—

Description.	South Austria.	North Austria.	Hungary.	Total.
Bessemer steelworks	6	4	2	12
Converters	17	11	6	34
Production in 1885 in tons . .	56,980	108,149	61,269	226,398
Working capacity in tons, from .	120,000	170,000	80,000	370,000
,, ,, ,, to . .	150,000	200,000	100,000	450,000

The production in 1885 was as follows :—

District.	Bessemer.		Open-Hearth.	Total.
	Acid.	Basic.		
South Austria	56,980	...	37,091	94,071
North Austria	31,308	76,841	3,930	112,079
Hungary	61,269	...	11,384	72,653
Total . .	149,557	76,841	52,405	278,803

---

* See Bell, "Principles of the Manufacture of Iron and Steel," p. 470.

Imports and Exports.—The following is an account of the imports and exports of iron and steel during 1884 and 1885:—

Description.	Imports.		Exports.	
	1885.	1884.	1885.	1884.
	Tons.	Tons.	Tons.	Tons.
Iron ore	37,698	32,557	52,837	38,330
Pig iron	49,250	92,827	9,650	5,709
Old iron	10,655	28,136	773	887
Rolled iron . . .	4,345	9,057	7,082	9,940
Rails	612	1,652	410	433
Plates	1,100	1,925	3,521	2,402

Iron and Coal in Hungary.—In a paper on the mineral resources of Hungary as shown at the Budapest Exhibition, read before the Society of Arts, Mr. B. H. Brough * gave the following statistics, showing the progress made by the Hungarian iron and coal industries within the last twenty years:—

Year.	Forge Pig Iron.	Foundry Pig Iron.	Coal.	Brown Coal.
	Tons.	Tons.	Tons.	Tons.
1864	108,000	8,300	350,000	250,000
1865	93,000	8,300	360,000	260,000
1866	98,000	9,000	400,000	280,000
1867	95,000	10,000	400,000	350,000
1868	101,000	11,900	490,000	450,000
1869	114,000	13,100	490,000	550,000
1870	113,000	11,900	550,000	600,000
1871	123,000	10,500	640,000	850,000
1872	138,000	10,300	650,000	950,000
1873	158,000	10,000	680,000	950,000
1874	157,000	10,200	620,000	780,000
1875	156,000	8,600	630,000	820,000
1876	117,000	10,200	640,000	880,000
1877	120,000	8,200	690,000	910,000
1878	130,000	10,400	690,000	910,000
1879	120,000	8,900	680,000	920,000
1880	133,000	11,400	800,000	1,020,000
1881	149,000	14,000	840,000	1,110,000
1882	161,000	13,900	800,000	1,260,000
1883	165,000	10,500	900,000	1,500,000

III.—*BELGIUM.*

Mineral Statistics.—The official statistics of the Belgian iron and coal trades for the years 1885 and 1884 are as follows:†—

---

* *Journal of the Society of Arts*, vol. xxxiv. pp. 265–277.

† *Le Moniteur Belge; Bulletin du Comité des Forges de France*, 1886, No. 229.

Description.	1885.	1884.
	Tons.	Tons.
Production of coal	17,346,771	18,051,499
Production of foundry pig iron	75,416	50,620
Production of forge pig iron	512,753	547,328
Production of pig iron for steel	126,498	152,864
Total of pig iron	714,667	750,812
Production of rails and plates	100,260	111,839
Other kinds of manufactured iron	353,967	359,201
Total production of manufactured iron	454,227	471,040
Cast steel	146,189	185,916
Steel rails, plates, &c.	116,119	153,999
Total production of steel	262,308	339,915

Imports and Exports.—The following figures show the Belgian imports and exports of iron and steel during 1885, as compared with 1884:—

Description.	Imports.		Exports.	
	1885.	1884.	1885.	1884.
	Tons.	Tons.	Tons.	Tons.
Iron ore	1,368,931	1,488,140	156,550	190,988
Cast steel (rough)	12	97	868	482
Steel rails	422	790	56,833	64,651
Other rolled steel	2,976	3,763	10,906	6,801
Wrought steel	461	558	1,913	2,427
Pig iron	100,788	125,619	10,667	10,665
Old iron	17,799	13,869	7,851	11,118
Iron wire	4,064	4,043	2,094	2,242
Iron rails	136	763	10,181	19,742
Plates	851	880	32,022	38,516
Other rolled iron	5,359	6,505	227,581	222,611
Nails	434	370	7,588	6,837
Wrought iron goods	2,751	2,705	23,093	21,670
Cast iron goods	549	912	19,408	12,253

The imports of coal and coke into Belgium during the years 1884 and 1885 were:—

Countries.	Coal.		Coke.	
	1885.	1884.	1885.	1884.
	Tons.	Tons.	Tons.	Tons.
Germany	387,211	438,578	13,130	21,423
England	305,441	298,284	3,615	1,323
France	123,112	78,673	5,214	8,818
Holland	421,633	408,124	...	...
Other countries	22	32	904	1,249
Total	1,237,419	1,223,691	22,863	32,813

The exports of coal and coke from Belgium during the years 1884 and 1885 were:—

Countries.	Coal.		Coke.	
	1885.	1884.	1885.	1884.
	Tons.	Tons.	Tons.	Tons.
France	3,993,936	4,340,259	752,833	772,927
Holland	129,725	120,034	...	...
Luxemburg	...	...	95,483	77,802
Other countries	213,660	158,899	8,105	3,529
Totals	4,337,321	4,619,192	856,421	854,258

IV.—*BORNEO.*

Production of Coal in Borneo.—The output of coal from the Government mines at Sadong shows an increase of 828 tons in 1884 above that in 1883, the quantities being 5866 tons against 5038 tons, and there appears a balance between receipts and expenditure on the mines of £18,197 to the good. There is a prospect that mining in the coalfield of Silanteck, which was carefully explored and surveyed ten years ago, but not hitherto worked, will be begun before long. One serious difficulty will be the laying of the lines of rails that will be needed for the traffic between the mines and the most convenient point for shipping, a distance of twenty miles, with deep swamps in many parts. Otherwise the undertaking presents no serious obstacles, and mining will be easy and inexpensive, owing to the favourable run of the seam.

V.—*CANADA.*

Mineral Production of Nova Scotia.—According to the report of Mr. E. Gilpin, inspector of mines, the amount of iron ore raised in 1885 was 48,129 tons. In 1884 the total was 54,885 tons. The output of coal was 1,352,205 tons in 1885, and 1,389,295 tons in 1884.

VI.—*CHINA.*

Coal in China.—Baron von Richthofen * has published particulars of the most recent discoveries in the search for coal now being diligently carried on in China by geologists of several nations. The author has himself explored fourteen out of the nineteen provinces into which China is divided, so that his statements may be accepted as at least approximately true. It appears from his account that not one of the nineteen provinces is wholly without coal; but the chief deposits are in the southern half of Chan-Si, in the south of Hunan, and in the west of Chan-Ting. The seams of Chan-Si alone cover an area of not less than 600 square miles, and contain 730,000,000,000 tons. As the total annual consumption of the world is about 300,000,000 tons, we have here enough to supply the demand for 2433 years. The quality is that of an excellent anthracite, superior to that of Pennsylvania. In the south-east of the same province there is another basin of scarcely less extent, containing coal of a more bituminous character. This coal is already being largely worked. The produce, which is obtained by a costly system of working, is sold at the pits at a price of which 3s. a ton is about the equivalent.

---

* *Iron and Coal Trades Review*, vol. xxxii. p. 453.

VII.—*FRANCE.*

Pig Iron, Manufactured Iron, and Steel.*—The following is a summary of the official records of the production of iron and steel in France for 1885:—

Pig Iron.

	Forge.	Foundry.	Total.
	Tons.	Tons.	Tons.
First half-year	642,411	186,955	829,366
Second half-year	615,937	183,638	799,575
	-26,474	-3,317	-29,791

Manufactured Iron.

	Rails.	Merchant.	Plates.	Total.
	Tons.	Tons.	Tons.	Tons.
First half-year	1,468	332,795	59,829	394,092
Second half-year	3,230	323,414	50,563	377,207
	+1,762	-9,381	-9,266	-16,885

---

* *Bulletin du Comité des Forges de France*, 1886, No. 230.

Steel.

	Rails.	Merchant.	Plates.	Total.
	Tons.	Tons.	Tons.	Tons.
First half-year	182,084	48,237	25,638	255,959
Second half-year	174,125	75,448	21,516	271,089
	−7,959	+27,211	−4,122	+15,130

As compared with 1884 there is a considerable reduction in the output of iron, both pig and manufactured, but an increase in steel; in fact, the quantity of the last named is the largest ever recorded. The production in the last four years is as follows:—

Year.	Pig Iron.	Manufactured Iron.	Steel.
	Tons.	Tons.	Tons.
1885	1,628,941	771,299	527,048
1884	1,871,537	876,751	502,908
1883	2,069,430	978,917	521,820
1882	2,039,067	1,073,021	458,238

Coal.—The production of coal in France in the second half of 1885 was 9,935,705 tons, and of brown coal 221,925 tons, against 9,162,555 tons of coal, and 214,156 tons of brown coal in the second half of 1884, an increase of 773,150 tons of coal, and 7769 tons of brown coal.

Imports and Exports.—The imports of iron and steel during the years 1885 and 1884 were * :—

Description.	1885.	1884.
	Tons.	Tons.
Pig iron	179,021	225,516
Finished iron	48,268	60,333
Old iron	4,278	13,253
Steel	13,518	19,378

In 1885 the quantity of iron and steel temporarily imported and re-exported after manufacture was :—

---

* *Bulletin du Comité des Forges de France*, 1886, No. 229.

Description.	Imports.	Re-Exports.
	Tons.	Tons.
Forge pig iron	65,663	72,064
Foundry pig iron	22,331	22,804
Manufactured iron	14,043	15,870
Steel of all kinds	4,681	8,395

The imports of iron ore during 1885 and 1884 were as follows:—

Countries.	1885.	1884.
	Tons.	Tons.
Belgium	105,939	182,516
Germany	594,080	528,578
Spain	564,524	457,807
Italy	2,408	42,475
Algeria	139,404	186,546
Other countries	13,166	14,802
Totals	1,419,521	1,412,724

The exports of iron ore from France during the same years were:—

Countries.	1885.	1884.
	Tons.	Tons.
Belgium	6,232	10,807
Germany	79,248	98,778
Other countries	3,751	10,552
Totals	89,231	120,137

Metal Sleepers.—M. Bricka, the State Railway engineer, who was sent by M. Raynal to study the question of metal sleepers on railways in Holland, England, Germany, Austria, and Switzerland, has published his report. The following table shows the extent to which metal sleepers have been used in three of these countries between 1878 and 1883:—

Year.	Length of Railways.	On Wooden Sleepers.	On Longitudinal Metal Sleepers.	On Cross Metal Sleepers.
		Germany.		
	Kilometres.	Kilometres.	Kilometres.	Kilometres.
1878	53,780	51,627	1,455	288
1879	56,298	52,615	2,539	789
1880	57,295	52,257	3,194	1,336
1881	58,164	51,836	3,806	2,000
1882	59,526	51,756	4,200	3,073
1883	69,803	51,627	4,666	4,009
		Holland.		
1878	2,848	2,667	1	80
1879	2,620	2,482	17	121
1880	2,772	2,564	17	191
1881	2,869	2,625	17	227
1882	3,101	2,824	17	260
1883	3,333	3,026	17	290
		Austria-Hungary.		
1878	24,158	24,139	19	1
1879	24,333	24,309	21	4
1880	24,577	24,547	26	4
1881	24,760	24,717	30	13
1882	25,581	25,519	44	18
1883	26,650	26,556	68	26

In Germany, it is apparent that the use of wooden sleepers is not being extended, while that of metal sleepers is increasing at the rate of 1000 kilometres annually, and at the end of 1883 there were 8675 kilometres. The employment of cross sleepers also finds more favour than that of longitudinal sleepers. In 1883 Holland had 307 kilometres of metal sleepers, but it is certain that during the last two years the extension has been at a considerably greater rate. Switzerland is the country in which the proportion of metal sleepers is largest. In 1884 there were 200 kilometres; last year 300. In Algeria, 100 kilometres of metal sleepers have been laid down.

VIII.—*GERMANY.*

Mineral Statistics.—The provisional official returns of the production of the German mines and works in 1885 are as follows:—

Description.	1885.	1884.
	Tons.	Tons.
Coal	58,293,873	57,233,875
Brown coal	15,267,477	14,857,879
Iron ore	9,061,988	8,922,454
Pig iron	3,652,634	3,562,726

Production of Pig Iron.—The production of pig iron in the German Empire, inclusive of Luxemburg, in the year 1885 was as follows:—

	Tons.
Forge pig iron	2,013,218
Spiegeleisen	143,079
Bessemer pig iron	472,468
Basic pig iron	668,065
Foundry pig iron	550,266
Total (estimated)	3,751,775
Total for 1884	3,572,155

Imports and Exports.—Kuhlow's *German Trade Review* gives the following statistics relative to the imports and exports of iron during the last three years:—

Description.		1885.	1884.	1883.
		Tons.	Tons.	Tons.
Pig iron	Imports	215,973·3	264,501·8	274,820·7
	Exports	213,534·5	230,007·8	259,014·2
Puddled iron	Imports	7,492·8	7,768·4	9,170·6
	Exports	63,230·0	67,108·6	92,503·8
Other manufactured iron	Imports	55,308·3	48,284·7	49,874·6
	Exports	762,655·6	764,958·2	772,213·2
Bar iron—Exports		144,466·9	154,004·8	146,988·8
Rails—Exports		164,791·3	144,452·6	176,177·5
Iron wire—Exports		193,093·1	212,793·7	203,627·2
Other rough iron goods—Exports		58,851·9	66,756·4	61,468·0
Rough iron plates—Exports		398·1	44,033·3	52,298·5
Wire nails—Exports		38,769·2	38,617·3	28,150·0
Cast iron goods—Exports		24,935·5	18,715·6	17,075·4
Forged iron pipes—Exports		17,102·1	19,046·7	19,540·2

The German imports and exports of coal and coke for the year 1885 were as follows:—

Countries.	Imports.	Exports.
	Tons.	Tons.
Bremen	2,750·2	313,200·7
Hamburg	371,459·1	319,063·2
Other free ports	3,019·1	28,542·6
Denmark	892·1	4,718·9
Norway	...	110·5
Sweden	...	5,019·8
Russia	324·2	312,234·6
Austria-Hungary	362,914·1	2,484,665·0
Switzerland	458·9	600,511·8
France	33,919·5	1,129,339·7
Belgium	55,718·5	741,536·0
Holland	28,439·2	2,947,256·3
England	1,515,819·0	3,117·5
Spain	0·1	1,074·5
Italy	...	59,207·6
United States	...	...
Other countries	191·1	5,919·4
Total, 1885	2,375,905·1	8,955,518·1
Total, 1884	2,296,777·0	8,816,934·8
Difference, 1885	+ 79,128·1	+138,583·3

IX.—*INDIA.*

Coal in India.—The following statement from Colonel Stanton's report on the working of the Indian railways gives the description of fuel used on the East Indian and guaranteed railways in India, the source whence it is obtained, and the average cost and consumption per train mile during the year 1884:—

Railway.	Source and Description of Fuel used.	Total Consumed.	Average Cost per Ton.	Per Train Mile.	
				Consumption.	Cost.
		Tons.	Rs	Lbs.	Rs.
East Indian	Bengal coal	195,208	1·93	48·47	0·67
Madras	Wood and patent fuel	99,621	5·07	91·69	3·32
South Indian	English and Australian coal	20,079	16·33	27·04	3·16
Great Indian Peninsula	English, Warora, Mophani, Bengal, and Umaria coal and wood	170,087	12·90	47·33	4·36
Bombay-Baroda	English coal and wood	40,835	16·34	46·55	5·43
Sind, Punjaub, and Delhi	English and Bengal coal, patent fuel, and wood	43,698	19·97	35·19	5·02
Oudh and Rohilkhund	Bengal coal	27,800	11·83	47·50	4·01

X.—*ITALY.*

Mineral Statistics.—The following are the official statistics relating to the production of iron ore and fuel in Italy in 1883:—

Description.	Mines.	Workmen.	Production.	Value.
			Tons.	Francs.
Iron ore	48	1,820	242,083	2,449,416
Manganiferous iron ore . .	1	289	9,000	114,000
Manganese ore . . .	4	200	11,384	274,480
Mineral fuel	26	2,237	214,421	1,686,399

XI.—*PORTUGAL.*

Mineral Statistics.—In the year 1882 the production of iron ores in Portugal was 24,351 tons. There were also produced 124 tons of manganiferous iron ores, 17,211 tons of manganese ore, 12,963 tons of anthracite, and 4409 tons of lignite.*

XII.—*RUSSIA.*

Russian Manganese Mines.—The manganese mines of the Charapan district, twenty-six miles from the nearest railway station at Kwirila, Southern Russia, are growing in importance. In 1884 the output was 12,050 tons, and in 1885 27,550 tons. The bulk of the ore goes to England.

Russian Steel Rails.—The following tables are from a statistical account relating to the production and consumption of steel rails in Russia, laid before the meeting of Russian iron metallurgists held at St. Petersburg in December 1885:†—

Works using their Own Material.

Works.	Tons.
Demidow—For the State	20,000
Do. —Not for the State	52,000
Balosersky—For the State	16,000
Do. —Not for the State	18,500
New-Russian—For the State	45,000
Do. —Not for the State	12,500
Huta Bankowa—For the State	...
Do. —Not for the State	53,000
Total .	217,000

---

* *Berg- und Hüttenmännische Zeitung*, vol. xliv. p. 501.

† *Stahl und Eisen*, vol. vi. p. 130.

Rolling Mills.

Works.	Tons.
Putilow, St. Petersburg	290,000
Alexandrowsky, „	60,000
Bransky, Mid-Russia	183,000
Warsaw Steelworks	132,000
Total	665,000

These latter works chiefly used British raw material.

The Wire Industry of Russia.—In the Governments of Moscow and Tver there are 680 wire-drawers, the value of whose output was estimated in 1881 at 368,000 roubles. Several of these establishments use machinery driven by horses, and employ from 30 to 50 workmen. The adult wire-drawer makes from 40 to 50 copecks per day." *

XIII.—*SPAIN.*

The Iron Industry of Spain.—The 39 ironworks existing in Spain in 1883 employed 6786 workmen, and produced 139,920 tons of pig iron, 2304 tons of weld iron direct from the ore, and about 50,000 to 60,000 tons from pig iron.

The imports of iron and steel were chiefly from the United Kingdom, and it is observed by G. Nordenström † that the British iron and steel imports into Spain increase every year in a far greater ratio than those of other countries. About one-half of all the forged and rolled iron produced in 1884—some 65,000 tons in all—comes from the Province of Oviedo, the chief producers being the Miéres Company, Duro & Company, and the Santander and Quirós Company. The first of these has works at Miéres, 48 kilometres south of Gijon, consisting of three blast furnaces, each 17·5 metres high, twenty-eight puddling furnaces, six reheating furnaces, rolling-mills, &c., and has an annual out-turn of 11,000 tons of forged and rolled iron.

The works of Duro & Co. are situated in the valley of Langreo, near the Vega railway station. They possess four blast furnaces, thirty-one puddling furnaces, with three steam-hammers, and three rolling-trains, seventeen reheating furnaces, and a train for rolling rails which was rebuilt in 1884. Their production is about 16,000 tons of forged and rolled iron.

---

* *Iron Age*, vol. xxxvii. No. 2.

† *Jern-kontorets Annaler*, vol. xl. pp. 69–190.

The other Company mentioned above possesses two blast furnaces at Quirós, each of them having a capacity of 160 cubic metres. The pig iron they produce is treated at the Company's works at Trubia, thirty kilometres distant, where there are sixteen puddling furnaces, three reheating furnaces, a large steam-hammer, and rolling-trains. The annual production reached in 1882 1150 tons of rails and 3250 tons of bar- and manufactured-iron.

Spanish Mines in 1883.—The production of iron ore, manganese ore, coal, and lignite was as follows :*—

Province.	Iron Ore.	Manganese Ore.	Coal.	Lignite.
	Tons.	Tons.	Tons.	Tons.
Almeria	83,820	1,579	...	...
Murcia	599,203	...	...	...
Oviedo	42,974	900	469,620	57
Santander . . .	83,256	...	...	1,750
Valencia . . .	...	...	216,443	...
Badajoz	700	...	...	...

Exports and Imports.—The following table shows the amount and value of the exports and imports of iron, iron ore, and fuel from and into Spain in 1884 and 1885 :†—

Description.	Quantity.		Value.	
	1885.	1884.	1885.	1884.
Exports.	Metric Tons.	Metric Tons.	Pesetas.	Pesetas.
Iron ore	3,784,544	3,967,607	34,060,895	35,708,643
Iron	32,672	29,365	2,747,611	2,451,582
Imports.				
Iron	71,983	102,843	16,997,879	22,142,144
Steel	3,984	1,353	318,701	108,272
Coal	1,317,247	1,342,032	26,344,940	26,840,640

Exports of Iron Ore from Bilbao.—The quantity of iron ore exported from Bilbao during the year 1885 was as follows :—

---

* *Revista Minera y Metalúrgica*, vol. xxxvi. pp. 294, 309, 325, 334, 349.

† *Ibid.*, vol. xxxvii. p. 132.

	Tons.
To Wales	999,992
„ North-East of England	630,767
„ Lancashire	10,856
„ Scotland	404,773
„ Other parts of Great Britain	4,131
Total to Great Britain	2,050,519
„ France	492,144
„ Belgium	171,771
„ Germany (through Holland)	572,520
„ United States	6,387
Total exported	3,293,341
Total in 1884	3,148,597
Increase	144,744

XIV.—*SWEDEN.*

Mineral Statistics.—According to Professor Åkerman, the production of iron and steel in Sweden in 1884 and 1883 was as follows:—

Description.	1883.	1884.
	Tons.	Tons.
Iron ore	885,124	909,553
Pig iron	422,627	430,534
Iron in bars, rods, &c.	255,853	264,944
Bessemer metal	50,878	53,123
Open-hearth metal	16,800	19,354
Other kinds of steel	1,827	1,764
Plates	17,439	17,534
Nails	8,197	9,720
Number of furnaces in blast	191	178
Average length of blast of each furnace, days	216	227
Average daily production of each furnace, metrical tons	10·25	10·67

At the end of 1884 there were in use in Sweden, in fourteen works, 20 open-hearths, of which four were each of 2 tons capacity, four of 2·5 tons, two of 3·5 tons, five of 4 tons, three of 4·5 tons, one of 5·5 tons, and one of a capacity of 6 tons.*

The total production of these works in 1884 was about 23,700 tons of ingots and 318 tons of castings, the total being about 3000 tons in excess of that of the previous year.

---

* *Jern-kontorets Annaler*, vol. xl. p. 377.

During 1884 there were also in course of construction one open-hearth for each of the following intended charges:—2·5 tons, 4 tons, 7 tons, and 8 tons.

Exports.—The exports of iron ore, iron, and steel from Sweden during the years 1885 and 1884 were as follows:—

Description.	1884.	1885.
Iron ore	40,000	25,817
Pig iron	55,000	47,521
Blooms	8,500	9,364
Iron in bars, rods, &c.	196,000	177,395
Plates of all kinds	2,400	3,288
Rails	1,800	2,190
Ingot iron and steel	10,500	4,158
Totals	314,200	269,733

XV.—*UNITED STATES.*

The Lake Superior Iron Ore Mines.—The shipment of iron ore from the Lake Superior mines in 1885 will be seen from the following table:*—

District.	1884.	1885.
	Tons.	Tons.
Marquette	1,660,250	1,383,799
Menorainee	795,674	699,640
Vermillion	62,000	225,484
Agogebic	...	109,563
Totals	2,517,924	2,418,486

The Cost of Production of Lake Superior Iron Ore.—The *Iron Age* † gives the following statements as representing the cost of production of iron ore at a typical older hard-ore mine, producing in six months about 90,000 tons of ore, and employing from 400 to 500 men. The cost of mining in six months of 1885 as compared with the same period of 1884 was distributed as follows, in percentages of the total cost:—

---

* *Iron Age*, vol. xxxvii. No. 2.

† Vol. xxxvii. No. 2.

	1884.	1885.
	Per cent.	Per cent.
Labour	58·82	63·00
Lumber	2·72	1·63
Fuel	5·69	6·79
Drill steel	0·46	1·04
Explosives	10·75	10·64
Supplies	16·45	15·84
Miscellaneous	5·61	1·10
Totals	100·50 *	100·04 *
Taxes	5·00	5·00

The following table gives the changes in price in some of the items entering into the cost of mining, computed on a percentage basis, between 1884 and 1885, calling 1884 100 per cent., the increase or decrease in the total quantity used, and the increase or decrease in the cost of the amount used, computed on a basis of tonnage output.

	Price.	Value of Total Quantity Used.	Cost of Amount Used per Ton.
	Per cent.	Per cent.	Per cent.
Wages	− 5½	− 2	+ 5·7
Lumber	...	−30	−28
Fuel	−10	+ 9	+18
Explosives	−15	− 8	− 5
Supplies	...	−13	− 3

Iron Ore in Ohio.—Mr. T. B. Bancroft, chief inspector of mines in Ohio, reports that the output of iron ore in the State of Ohio in 1885 was approximately as shown in the following table:—

County.	1884.	1885.
	Tons.	Tons.
Columbiana	8,800	14,132
Hocking	5,332	...
Jackson	48,958	64,126
Jefferson	22,219	...
Lawrence	88,901	82,691
Mahoning	37,240	20,000
Perry	7,450	11,700
Scioto	9,281	12,842
Tuscarawas	18,000	38,250
Trumbull	184	12,685
Vinton	29,921	3,036
Gallia	...	119
Totals	276,286	259,581

---

* 100·00 in original.

In 1885 the product of Mahoning, Trumbull, and Tuscarawas counties was blackband; that of the other counties was hæmatite.

Iron Ore in New Jersey.—The State Geologist's statistics* of the production of iron ore in New Jersey show 330,000 tons for 1885, as against 393,710 tons for 1884. The falling off since 1882, when the production was 932,762 tons, is very marked. It is, however, not due to exhaustion of the mines, but to the development of other sources of supply.

The Production of the Hibernia Iron Mine, New Jersey.—According to Mr. J. W. Pullman,† the actual shipments of ore from the Hibernia mine for the twenty-two years from January 1, 1864, to December 31, 1885, amounts to 1,641,437 tons. Estimating the stock piles at the mines and docks, January 1, 1886, as 75,000 tons in excess of the stocked ore, January 1, 1864, the total ore actually raised during the twenty-two years is 1,716,437 tons, being an annual average yield of 78,020 tons. This exceeds very considerably the output of any other mine in New Jersey. In 1880 the output was 145,029 tons; in 1881 it was 144,098 tons; and in 1882 it was 135,652. The average yearly production is very much below the developed capacity.

In his paper the author traces the history of the mine back to 1710, giving a number of letters of J. Hoff (1776) concerning the operations of the Hibernia furnaces when employed in casting cannon and shot for supplying the American army.

Manganese Ore in the United States.—According to the special report of Mr. J. D. Weeks, in the volume of *Mineral Resources of the United States for* 1885, the production and value of manganese ores in 1885 were as follows, in tons of 2240 lbs. :—

State.	Tons.	Value in Dollars.
Virginia	18,745	168,942
Georgia	2,580	13,390
Arkansas	1,483	5,932
Other States	450	2,017
Manganiferous iron ore from Virginia . .	3,237	17,318
Totals	26,495	207,599

---

* *Geological Survey of New Jersey, Annual Report of the State Geologist for the year* 1885. Trenton, 1886.

† Paper read at the Pittsburg meeting of the American Institute of Mining Engineers, February, 1886.—*Transactions*, vol. xiv. pp. 904–913.

Under the head of manganiferous iron ores are included all iron ores with less than 44·25 per cent. of manganese. In Montana, 4263 tons of argentiferous manganese ores were producėd. They are only used for their contents of silver. The production of manganese ores (containing over 44·25 per cent. of manganese) in the United States since 1880 has been as follows:—

Year.	Tons.
1880	5,761
1881	4,895
1882	4,532
1883	6,155
1884	10,180
1885	23,258

The production of spiegeleisen and ferromanganese in the United States in 1885 was 30,955 tons.

The Output of Coal in the United States.—Mr. F. Saward* gives the following estimate of the production of coal in the United States during 1885; it differs considerably from other estimates:—

State, &c.	1884.	1885.
	Tons.	Tons.
Alabama	2,000,000	2,225,000
Arkansas	150,000	175,000
California	200,000	150,000
Colorado	1,200,000	1,350,000
Dakota	50,000	75,000
Georgia	200,000	200,000
Idaho	20,000	40,000
Illinois	10,101,005	9,791,874
Indiana	2,260,000	2,375,000
Indian Territory	400,000	500,000
Iowa	3,903,458	3,585,737
Kansas	1,100,000	1,300,000
Kentucky	1,550,000	1,700,000
Maryland	2,469,051	2,462,485
Michigan	135,000	130,000
Missouri	2,500,000	2,750,000
Montana	50,000	75,000
New Mexico	220,557	306,207
Ohio	9,000,000	9,000,000
Oregon	60,000	100,000
Pennsylvania, anthracite	30,718,293	31,623,529
Pennsylvania, bituminous	25,000,000	25,000,000
Tennessee	1,200,000	1,440,597
Texas	125,000	175,000
Utah	250,000	250,000
Virginia	300,000	650,000
Washington Territory	380,698	410,667
West Virginia	3,000,000	3,483,457
Wyoming	1,000,000	900,000
Totals	99,543,062	102,224,553

---

* *The Coal Trade.* New York, 1886.

The Manufacture of Coke in the United States in 1885.—According to Mr. J. D. Weeks, the amount of coke produced in the United States in 1880, 1884, and 1885, by States and Territories, was as follows, in tons of 2000 lbs. :—

State, &c.	1880.	1884.	1885.
Alabama	60,781	244,009	301,180
Colorado	25,568	115,719	131,960
Georgia	38,041	79,268	70,669
Illinois	12,700	13,095	10,350
Indian Territory . . .	1,546	1,912	3,584
Kansas	3,070	7,190	8,050
Kentucky	4,250	2,223	2,704
Montana	...	75	175
New Mexico	...	18,282	17,940
Ohio	100,596	62,709	39,416
Pennsylvania	2,821,884	3,822,128	3,991,805
Tennessee	130,609	219,723	218,842
Utah	1,000	...	...
Virginia	...	63,600	49,139
Washington	...	400	311
West Virginia	138,755	223,472	260,571
Totals . .	3,338,800	4,873,805	5,106,696

Other statistics relating to the manufacture of coke in the United States during the same years are as follows :—

	1880.	1884.	1885.
Number of works	186	250	233
Ovens built	12,372	19,557	20,116
Ovens building	1,159	812	432
Coal used, tons of 2000 lbs. . .	5,237,741	7,951,974	8,071,126
Total value of coke at ovens . .	$6,631,267	$7,242,878	$7,629,118
Value of coke at ovens, per ton .	$1·99	$1·49	$1·49
Yield of coal in coke, per cent. .	63	61	63

Alabama Coal, Coke, and Iron.—In 1872 only 10,000 tons of coal were mined in the State of Alabama; in 1880 the quantity produced reached 340,000 tons.* Since that date the progress of the coal-mining industry has been exceedingly rapid, and in 1885 the production reached 2,225,000 tons.

In 1880 there were in Alabama 316 coke-ovens; in 1884 this number had increased to 976, and it is considered that at the commencement of 1886 some 1200 ovens were at work.

* *Iron Age*, vol. xxxvii. No. 8.

The quantities of coal used in the ovens and of the coke produced in the years 1880–85 were as follows :—

Year.	Tons.	
	Coal Used.	Coke Produced.
1880	106,283	60,781
1881	184,881	109,033
1882	261,839	152,940
1883	359,699	217,531
1884	413,184	244,009
1885	515,550	304,509

The coke sells at from 2·5 to 3 dollars per ton.

With the exception of Pennsylvania, Alabama is the largest coke-producing State, West Virginia ranking third.

The production of pig iron is gradually increasing. In 1876, 24,732 tons were made; in 1880, 77,190 tons; and in 1884, 189,660 tons. The production for 1885 is estimated to be about the same as for 1884.

Blast Furnaces in the United States.—At January 1, 1886, the condition of the blast furnaces in the United States was as follows :*—

Fuel.	In Blast.		Out of Blast.	
	Number.	Weekly Capacity.	Number.	Weekly Capacity.
		Tons.		Tons.
Charcoal	57	7,804	169	16,678
Anthracite	104	29,811	117	25,518
Bituminous	114	54,199	106	40,508
Totals	275	91,814	392	82,704

Since December 1, 1885, twenty-one more furnaces have been blown in, this number being made up as follows :—

Increase in anthracite furnaces	10
„ bituminous furnaces	15
Decrease in charcoal furnaces	4
Total increase	21

---

* *Iron Age*, vol. xxxvii. No. 1.

A year ago the condition of the furnaces and the capacity were as follows:—

Fuel.	In Blast.		Out of Blast.	
	Number.	Weekly Capacity.	Number.	Weekly Capacity.
		Tons.		Tons.
Charcoal . . .	68	8,371	159	15,941
Anthracite . .	86	21,564	135	28,500
Bituminous . .	82	36,812	141	55,812
Totals . .	236	66,747	435	100,253

The number of anthracite and bituminous furnaces in blast at the beginning of each month of the last year and the first month of the present, together with their weekly capacity, is as follows:—

Date.	Anthracite.		Bituminous.	
	Number in Blast.	Weekly Capacity.	Number in Blast.	Weekly Capacity.
		Tons.		Tons.
January 1, 1885 .	86	21,564	82	36,812
February 1 ,, . .	81	21,189	87	46,653
March 1 ,, . .	86	22,889	91	46,774
April 1 ,, . .	82	21,704	90	45,655
May 1 ,, . .	80	20,729	95	43,397
June 1 ,, . .	79	19,834	94	44,498
July 1 ,, . .	81	20,444	92	43,945
August 1 ,, . .	77	20,530	86	44,845
September 1 ,, . .	78	20,190	88	42,663
October 1 ,, . .	75	20,318	88	43,234
November 1 ,, . .	86	24,270	89	44,101
December 1 ,, . .	94	26,816	99	49,790
January 1, 1886 .	104	29,811	114	54,199

The Production of Pig Iron in the United States in 1885.—According to the statistics of the American Iron and Steel Association,[*] the production of pig iron in the United States during 1885 was as shown in the following table:—

[*] *Bulletin of the American Iron and Steel Association*, vol. xx. p. 21.

State.	Production. Tons of 2000 lbs.		
	First Half of 1885.	Second Half of 1885.	Total for 1885.
Maine	...	440	440
Massachusetts	...	869	869
Connecticut	7,017	10,483	17,500
New York	75,191	84,966	160,157
New Jersey	28,014	45,653	73,667
Pennsylvania	1,167,855	1,277,641	2,445,496
Maryland	8,383	8,916	17,299
Virginia	74,627	89,155	163,782
North Carolina	820	970	1,790
Georgia	7,644	25,280	32,924
Alabama	118,186	109,252	227,438
Texas	1,000	843	1,843
West Virginia	35,965	33,042	69,007
Kentucky	16,768	20,785	37,553
Tennessee	79,144	82,055	161,199
Ohio	273,060	280,903	553,963
Indiana	3,594	3,040	6,634
Illinois	141,476	186,501	327,977
Michigan	66,557	76,564	143,121
Wisconsin	17,867	6,765	24,632
Missouri	18,505	32,903	51,408
Minnesota	...	...	...
Colorado	5,481	...	5,481
Oregon	1,805	2,027	3,832
California	...	...	...
Washington Territory	1,857	...	1,857
Total, 1885	2,150,816	2,379,053	4,529,869
Total, 1884	2,267,021	2,322,592	4,589,613

Anthracite pig iron was produced in New York, in New Jersey, and in Pennsylvania. Nearly all the pig iron that has been produced in late years in anthracite furnaces has really been made with a mixture of anthracite and coke; very little being made with anthracite alone. In 1884, only 246,570 tons were produced with anthracite alone, and in 1885 only 277,913 tons were produced.

The stocks of unsold pig iron in the hands of the manufacturers at the close of 1885, not required for the consumption of those who produced it, amounted to 416,512 nett tons or 371,886 gross tons. More than half of this quantity was charcoal pig iron.

Production of Iron and Steel in the United States in 1885.—The following is a summary of the returns given in the annual report of the American Iron and Steel Association, in tons of 2000 lbs. :—

Description.	1884.	1885.
	Net Tons.	Net Tons.
Bituminous pig iron	2,544,742	2,675,635
Anthracite pig iron	1,586,453	1,454,390
Charcoal pig iron	458,418	399,844
Total pig iron	4,589,613	4,529,869
Spiegeleisen (included above)	33,893	34,671
Bessemer steel rails	1,116,621	1,074,607
Iron rails	25,560	14,815
Open-hearth steel rails	2,670	4,793
Total rails	1,144,851	1,094,215
Street rails (included above)	31,357	35,990
Bessemer steel ingots	1,540,595	1,701,762
Crucible steel ingots	59,662	64,511
Open-hearth steel ingots	131,617	149,381
Blister and puddled steel	5,111	1,696
Total steel of all kinds	1,736,985	1,917,350
Cut nails, kegs	7,581,379	6,696,815
Cut iron nails, tons	379,069	243,684
Plate and sheet iron, except nail-plate	322,584	345,069
Bar, hoop, and shaped iron	1,230,094	1,200,958
Total rolled iron, including nail-plate and iron rails	1,957,307	1,804,526
Iron blooms and billets from ore	29,789	19,887
Iron blooms from pig and scrap	27,216	21,813
Total iron blooms	57,005	41,700

The Cost of Production of Pig Iron in the United States.—Mr. C. D. Wright, the United States Commissioner of Labour, gives in his first Report the following statistics relating to the cost of production of pig iron in the United States. The period to which the Report refers closely coincides with the time of lowest costs in 1885, since when there has been a general advance in prices :—

State.	Grade.	Labour.	Materials.	Administration.	Other.	Total.
		Dollars.	Dollars.	Dollars.	Dollars.	Dollars.
Alabama	Foundry	1·87	6·92	0·36	2·34	11·49
Indiana	,,	1·90	10·90	...	...	12·80
New York	,,	1·547	9·516	0·190	0·577	11·83
Ohio (Lake ore)	,,	1·305	12·688	...	0·817	14·810
Do. (Hocking Valley and Lake ore)	,,	2·00	11·30	...	0·75	14·05
Do. (Hanging Rock ore) .	,,	1·20	10·15	0·15	0·37	11·87
Do. do. do. . .	,,	1·50	9·80	0·44	0·70	12·44
Do. do. do. . .	,,	1·80	11·95	0·50	0·50	14·75
Do. (Mahoning Valley and Lake ore)	,,	1·40	12·17	0·10	1·50	15·17
Do. (Mahoning Valley and Lake ore)	,,	1·25	12·62	...	0·75	14·62
Tennessee	,,	1·83	10·01	...	0·79	12·63
Do.	,,	2·17	10·82	...	...	12·99
Virginia	,,	1·282	9·010	0·231	1·141	11·664
Do.	,,	1·169	10·476	0·541	0·500	12·686
Do.	,,	1·114	10·700	0·150	0·252	12·216
West Virginia (Lake ore) .	,,	2·100	13·325	0·310	0·795	16·53
Do. do. (West Virginia ore)	,,	1·500	10·950	...	1·000	13·45
Maryland	,,	2·481	14·773	...	...	17·254
New York	,,	2·180	13·928	0·257	0·043	16·408
Ohio	Bessemer	1·188	15·015	0·150	0·305	16·658
Do.	,,	2·50	14·90	0·50	0·50	18·40
Do.	,,	2·50	14·90	...	1·00	18·40
Pennsylvania	,,	1·22	14·76	0·75	...	16·73
Do.	,,	1·14	13·91	0·75	0·75	16·55
Do.	,,	1·50	13·86	0·75	1·50	17·61
Ohio (Ohio brown hæmatite) .	Silvery soft	2·29	10·06	0·50	0·60	13·45
Do. do. do. .	,,	2·10	10·42	0·40	0·50	13·42
Do. do. do. .	,,	1·85	10·07	0·33	0·50	12·75
Do. do. do. .	,,	1·95	10·07	0·40	0·50	12·92
Do. do. do. .	,,	2·00	10·62	0·50	0·50	13·62
Do. do. do. .	,,	2·00	10·22	...	0·75	12·97
Pennsylvania	No. 1 mill	1·40	10·50	1·50	1·00	14·40
Do.	,,	2·00	11·97	0·40	0·58	14·95
Do.	Low mill	1·50	9·12	0·75	1·50	12·87

The Production of Bessemer Steel and of Iron and Steel Rails in the United States in 1885.—The American Iron and Steel Association* has published the following statistics of the production of Bessemer steel in the United States in 1885.

The production of Bessemer steel ingots was 1,701,757 nett tons, or 1,519,426 gross tons, an increase of 161,162 nett tons over the production in 1884. The production of 1885 was the largest ever made. In the following table it is given in comparison with that of the three preceding years :—

---

* *Bulletin of the American Iron and Steel Association*, vol. xx. p. 36.

State.	Tons of 2000 lbs.			
	1882.	1883.	1884.	1885.
Pennsylvania	933,631	1,044,396	1,031,484	1,109,034
Illinois	397,436	273,325	339,068	366,659
Other States	365,383	336,906	170,043	226,064
Totals . .	1,696,450	1,654,627	1,540,595	1,701,757

Pennsylvania made 65 per cent. of all the ingots produced in 1885, Illinois made 22 per cent., and other States made 13 per cent. In 1884, Pennsylvania's share was 67 per cent., that of Illinois was 22 per cent., and that of the other States was 11 per cent. Included in the production of ingots in 1885 were 21,647 nett tons of Clapp-Griffiths ingots which were made by Oliver Brothers & Phillips at Pittsburg. This product was made from April 3 to the close of the year. No other Clapp-Griffiths plant was in operation in the United States in 1885. In 1886 there will be several plants in operation.

The production of Bessemer steel rails in the United States in 1885 was 1,074,607 nett tons, or 959,470 gross tons, a decrease of 42,014 nett tons on the production of 1884. The production of 1885 was less than in any year since 1880, when it was 954,460 nett tons. In the following table is given the production of Bessemer steel rails from 1881 to 1885 :—

States.	Tons of 2000 lbs.				
	1881.	1882.	1883.	1884.	1885.
Pennsylvania . . .	688,276	759,524	819,544	763,223	736,522
Illinois	346,272	336,122	231,355	290,185	308,242
Other States . . .	295,754	342,509	235,655	63,213	29,843
Totals . .	1,330,302	1,438,155	1,286,554	1,116,621	1,074,607

Pennsylvania made 68 per cent. of all the Bessemer steel rails produced in 1885, Illinois made 29 per cent., and other States made only 3 per cent. In 1884 Pennsylvania's share was 68 per cent., that of Illinois was 26 per cent., and that of other States was 6 per cent.

The production of rails of all kinds in the United States in 1885 was 1,090,699 nett tons, or 973,838 gross tons, a decrease of 54,152 nett tons on the production of 1884. The production of rails of all kinds in 1885 was less than in any year since 1878, when it was 882,685 nett tons. The production of rails of all kinds since that year is given in the following table :—

Year.	Tons of 2000 lbs.				
	Bessemer.	Open-Hearth.	Total Steel.	Iron Rails.	Total Iron and Steel.
1878	550,398	9,397	559,795	322,890	882,685
1879	683,964	9,149	693,113	420,160	1,113,273
1880	954,460	13,615	968,075	493,762	1,461,837
1881	1,330,302	25,217	1,355,519	488,581	1,844,100
1882	1,438,155	22,765	1,460,920	227,874	1,688,794
1883	1,286,554	9,186	1,295,740	64,954	1,360,694
1884	1,116,621	2,670	1,119,291	25,560	1,144,851
1885	1,074,607	1,400	1,076,007	14,692	1,090,699

One of the most significant deductions to be drawn from the foregoing statistics is the increasing use of Bessemer steel for miscellaneous purposes as a substitute for iron. In 1882 the proportion of Bessemer steel ingots which was converted into rails was 85 per cent., in 1883 it was 78 per cent., in 1884 it was 72 per cent., and in 1885 it was 63 per cent.

The Bessemer Steel Industry of the United States.—According to the *Bulletin* of the American Iron and Steel Association,* the Bessemer steel industry is no longer confined to a few establishments situated in three or four States. Twenty-four Bessemer steelworks now exist in no less than nine States, namely, Massachusetts, New York, New Jersey, Pennsylvania, Ohio, West Virginia, Illinois, Missouri, and Colorado, while ten more works scattered over some of the States named are in course of erection and fast nearing completion, and others are projected. Omitting the Pottstown Iron Company's plant, of which there is as yet no definite information, the completed and partly finished works contain converters as follows :—Completed works—ten 10-ton, five 8-ton, ten 7-ton, six 6-ton, eight 5-ton, eight 4-ton, two 3-ton, three 2-ton, and one 1½-ton ; partly finished works—three 7-ton, two 5-ton, and nine 3-ton. Total, sixty-seven converters, of which fifty-three are completed and fourteen partly finished.

---

* Vol. xx. p. 33.

With reference to the Clapp-Griffiths plants now under construction, Mr. Witherow states that each one is to have two 3-ton converters, provision being made for an additional converter where one is being built. The two 2-ton converters of Oliver Brothers & Phillips, he adds, now average from 160 to 175 tons in twenty-four hours, and could work to over 200 tons, but they have to work under the disadvantage of having no blooming-mill for their ingots.

There is not one basic Bessemer plant in the country, with the exception of the old Bessemer plant of the Pennsylvania Steel Company, which was worked experimentally for a short time on basic steel with unsatisfactory economic results.

United States Imports and Exports of Coal.—The imports and exports during the year 1885, as compared with those of the preceding year, were, according to the Bureau of Statistics, as follows:—

Description.	1885.	1884.
Imports.	Tons.	Tons.
Bituminous coal	792,472¾	801,077
Exports.		
Anthracite	645,310	643,066
Bituminous coal	540,736	698,952

UNIVERSITY OF MICHIGAN
3 9015 06810 9514